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MONANA

JOURNAL of the AUSTRALIAN METEOROLOGICAL ASSOCIATION (INC.)

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Vol. 3 No. 4, November, 1988

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AUSTRALIAN METEOROLOGICAL ASSOCIATION INCORPORATED

PRESIDENT'S REPORT FOR 1987-1988

(Delivered to the Society on 17 August, 1988)

The Australian Meterological Association (AMetA) was formed in Adelaide in 1969 with the objective of bringing together people with an interest in meteorology.

No academic qualifications for membership have been required and all the talks given have been made as non-technical as possible. However, at times some technical explanations have been necessary to explain unusual meteorological situations.

Speakers at AMetA meetings have come from all walks of life; the programme has included a professional fisherman, a research worker on tides and ocean waves, a Forestry Fire Protection Officer, an expert on gliding, and many others who spoke about subjects on which the weather has direct bearing.

Meetings of the AMetA are presently held at two-monthly intervals and the association publishes "Monana" a journal which contains reports of these meetings as well as other typical weather material. Meetings are held in the Conference Room of the Bureau of Meteorology located at 25 College Road in Kent Town.

Due to problems largely associated with obtaining a suitable secretary/treasurer, the association went into recess in 1983. It was reactivated early in 1986, and on 20 August of 1986 the first Annual General Meeting since 1982 was held at which a new committee was elected. Details of the committee, the program for the past two years, the association journal and the present financial position, follow:

1. Committee:

The committee, which was voted into office on 20 August, 1986, for a period of two years consisted of:

President:	Dr. John Noye
Vice-President:	Mr. Allan Brunt
Secretary/Treasurer:	Mr. Peter Webb
Six Committee Members:	Mr. Graeme Furler
	Mr. Bill Slaytor
	Mr. Lynn Mitchell
	Mr. Adrian Gordon
	Mr. Warren Wright
	Mr. Terry Keen.

2. The Year's Program:

The talks given during the last two years were:

20 August 1986:	"Research projects in the Bureau of Meterology" by Mr. Warwick Grace.
15 October 1986:	"Climate response to solar variability – evidence from the geological record" by Mr. George Williams.
18 February 1987:	"Weather associated with the British atomic tests" by Mr. Adrian Gordon.
15 April 1987:	"VHF Radar and its future applications" by Mr. Andrew Watson.
17 June 1987:	"The greenhouse effect" by Mr. Graeme Crooks.
19 August 1987:	"Meteorological optics of a UFO kind" by Mr. Allan Brunt.
28 October 1987:	"The Adelaide gully wind" by Mr. Ian Holton.
17 February 1988:	"Nocturnal winds over Adelaide" by Mr. Warwick Grace.
13 April 1988:	"The R101 airship disaster" by Mr. Adrian Gordon.
15 June 1988:	"Airborne Meteorological research at Flinders University" by Dr. Jorg Hacker.

and tonight

17 August 1988: "Sea-level and climate" by Professor Geoff Lennon.

The average attendance for the 1986-87 year was 24, which increased to 31 for the 1987-88 year.

3. Membership:

Our membership at present totals 66, consisting of 50 full members, 8 affiliate members, 4 pensioners, 3 students and 1 honorary member.

The aim is to again reach the figure of 100 which existed before the association went into recess at the beginning of 1983. If you know of anyone interested in joining the association please invite them to one of our meetings so they can hear the talks given and we can meet them over a cup of tea or coffee.

4. Financial Statement:

Because the membership fees collected in 1986 covered the two years 1986-87 and only fees from new members were collected during 1987, expenditure in 1987 exceeded income by $177. However, for the 1987-88 financial year there has been an excess of income over expenditure of $248. The finances are in a sound state, the balance of accounts being $1674.

Last year it was regretfully decided that membership fees had to increase, after thirteen years without change. The new fees are:

Full member	:	$8.00
Affiliate	:	$4.00
Student	:	$2.00
Junior	:	$2.00
Pensioner	:	$2.00

However, those who attend our meetings and enjoy the free tea/coffee and biscuits afterwards, will agree that these amounts are more than reasonable.

5. Monana:

For the first time since 1982, the association journal, "Monana", was published this year. The new editor, Bill Slaytor, prepared the material given to him so it was suitable for publication. Considerable assistance in the preparation of the journal was given by Warren Wright and Graeme Furler. In future this journal will be published annually.

6. Acknowledgements:

Special thanks must go to a number of people. Firstly, I wish to thank all speakers for their excellent presentations. Secondly, members who braved the rain and cold to attend our recent meetings are to be commended for their effort. Thirdly, our energetic secretary/treasurer, Peter Webb, continues to issue and circulate newsletters with meeting notices, which is no small task. Anyone with short items of interest is welcome to approach Peter as he is looking for material to use. I would also like to thank John Armstrong for carrying out necessary secretarial duties whenever Peter cannot attend meetings, and for being Acting Secretary for the six months when Peter was transferred to Mount Isa. Finally, special thanks go to the Regional Director of the Bureau of Meteorology in South Australia, Graeme Furler, for the assistance and encouragement he has given to the association.

John Noye,
President.

17 August, 1988.

THE ADELAIDE GULLY WIND

Ian Holton
South Australian Regional Office
Bureau of Meteorology

The Adelaide Gully Wind is an interesting meso-scale wind that occurs in the lee of the Mount Lofty Ranges in an easterly synoptic situation. Figure 1 shows the location. This fresh to strong and often gusty wind normally springs up around sunset and continues to blow throughout the night until sometime after sunrise, when it ceases abruptly. It occurs predominantly in the summer and near-summer months.

For some people, the gully winds bring relief from the heat of a summer's day, but for others they are a nuisance, blowing nearly every day for weeks on end, raising dust and causing house and garden damage. There is even a firm which capitalises on the tree damage - "Gully Wind Tree Loppers". Sometimes the wind causes extensive structural damage. Fortunately these occasions are normally limited to once or twice a year. An example: "Wind storm lashes city, suburbs ...the state emergency service was called to about seventy different locations yesterday morning after ninety-six kilometre per hour wind storm dislodged trees onto house roofs, blew roofs off and cut power lines" (The Advertiser, 12 November 1967).

The gully winds also pose hazards to aviation traffic since turbulence and wind shear are often associated with their occurrence. Even road traffic is not immune to inconvenience, as shown by the fact that late last century in the days of Adelaide's horse trams extra horses were required to pull trams from Parkside to Glen Osmond when strong gully winds were blowing (Kingsborough, 1967).

Recent Research into Adelaide Gully Wind Flow

Although gully winds have been observed for many years, little research on their formation has been done until quite recently. Holton, (1985) and Marsh, (1987), did some of the first pioneering work, but the most recent research has been carried out by Grace and Holton (1988). The results of their study of the 1986/87 summer gully wind season are outlined in this article.

Gully Wind Causes

One of the most popular recent theories was that at night easterly winds were converged through a subsidence inversion (increase of temperature with height), and the ridge top of the Mount Lofty Ranges. In this sense the inversion was seen to be acting as a "lid" on the low level wind flow. This strengthened flow was then thought to be converged further by flow down the valleys and gullies of the lee slopes, in much the same way as

water would flow. However, we now feel confident that both of these mechanisms are either incorrect or of small importance in forming the gully winds.

The gully wind appears to be a form of downslope wind that occurs in the lee of mountain ranges all over the world, and the term downslope wind is preferred. Some well-known examples are the Foehn and Bora of Europe and the Chinook of North America. Although the reasons for the downslope wind are still unknown, several theories have been put forward for their formation. The most popular of these involves a complex interaction of atmospheric waves (Klemp and Lilly, 1975; Peltier and Clark, 1979, and Durrand, 1986). The theory developed by Grace and Holton, (1988), however, is quite different, and has more in common with hydraulic theory than with atmospheric wave theory.

In their theory, gully wind flow is initiated by gravitational acceleration of cool, dense boundary layer air descending from the Mount Lofty Ranges ridge top. This cool dense air originates in three ways:

(a) cool Coorong sea-breeze air is forced up the eastern flank of the Mount Lofty Ranges by coriolis force (caused by the earth's rotation) and/or by the shearing stress or drag of the general easterly flow aloft;
(b) adiabatic cooling of the flow as it is forced up the windward slope, that is, approximately 1 deg C per 100 metres of vertical ascent (Mt. Lofty is approximately 736m above sea level) and
(c) radiational cooling.

By these three means, air at the summit may be up to 12 degrees cooler than air at the same level over the Adelaide Plains. This air therefore accelerates down the lee slopes to the Adelaide Plains where eventually the buoyancy contrast is destroyed. the temperature between the air at the summit and air at the same level over the Adelaide Plains will hereafter be referred to as Delta T. This Delta T is calculated by subtracting the temperature recorded at the Mt.Lofty Automatic Weather Station from that recorded by the Adelaide Airport radiosonde balloon at 736m.

Delta T and Gully Wind Speed

An anemometer (wind recording device) was set up at a well exposed lee site at Wattle Park, an Adelaide foothills suburb, in November 1986. This anemometer site provided evidence of a relationship between Delta T and gully wind strength. Figure 2 shows the variation with time of both of these parameters during a typical gully wind night. It can be seen that the overnight easterly wind speed increases as the Delta T value increases, and decreases as the Delta T value decreases. Figure 3 shows three different overnight wind traces at Wattle Park, one with a maximum Delta T value of 10 deg C, another with a value of 5.2 deg C, and yet another with a value of zero. It can be clearly

seen how the overnight mean wind speed increases as Delta T reaches higher values.

Not surprisingly then, the most extreme gully wind events tend to occur with high values of Delta T and with strong geostrophic synoptic easterly flow. Such damage situations normally occur with shallow cold frontal passages embedded in fresh to strong south-easterly geostrophic synoptic events. In these cases, the cold front takes the place of the Coorong sea-breeze.

Day/Night Variations

Why do gully winds blow mainly at night? They blow mainly at night because:

(a) The Coorong sea-breeze forms during the daytime, but normally only attains sufficient inland penetration to pass over the Mt.Lofty ridge late in the evening.

(b) Radiational cooling during the night is replaced by solar and convectional heating of the surface boundary layer during the daytime. For this reason adiabatic cooling will not produce any temperature difference (Delta T) during the mid-daylight hours. (Fig. 4)

Hydraulic Jump Effects

As the gully wind flow descends it will eventually flow into slower moving air over the plains. Where this occurs, a line of turbulent up-motion is formed. In the terminology of fluid hydraulics this is termed an "hydraulic jump". An example of this can be seen as water spills down a dam wall into the relatively stagnant water below. For the gully wind case, substitute cool, dense air for water.

This jump line, parallel to the ridge top orientation, will separate the strong gully flow from the lighter or even reverse flow on the other side. The strongest wind will always be nearest the hill-side. As this hydraulic jump moves up and down the lee slope and out and back onto the plains, it will cause sudden wind speed and direction changes. Many Adelaide hill-side residents will have noticed these "lulls" and "surges" in the gully wind flow over-night. As the hydraulic jump passes a point as it moves toward the coast (either because Delta T or the geostrophic wind flow has increased) so the local wind speed will rise rapidly, and vice-versa. This effect of the hydraulic jump retreating towards the hills in the morning, as solar heating destroys the Delta T effect, is the cause of the very suden ending of the gully wind shortly after sunrise. If the hydraulic jump remains stationary near a point, strong winds may be heard roaring in the trees to the east, while almost calm conditions exist at the observation point. This last-mentioned effect is commonly reported by some suburb dwellers and figure 5 shows an example of an hydraulic jump moving up and back in a gully wind flow.

The other main feature of the hydraulic jump is that it causes a turbulent updraft near its forward edge. This is the likely cause of turbulence reported by air traffic in the vicinity of the Adelaide lee slope and plains. One pilot reported that often when he flew near the east parklands (Kent Town) area of Adelaide, he experienced very strong up and down drafts, while over the west parklands, conditions were normally quite smooth (Holton and Grace, 1988a).

Kitchen Tap Experiment

The above hydraulic jump effects can be demonstrated by running the kitchen tap into the flat metal bowl underneath. As the flow moves out from the impact point it resembles the strong gully wind flow. Then further away from this fast moving area is an hydraulic jump ring, or part of a ring, where the flow "jumps up" and then becomes much slower moving. As the tap is turned on faster, so the hydraulic "ring" moves further out from the impact point and turbulent bubbles begin to form near the top of the ring.

Other "Gully Wind" Areas in Australia

Downslope winds similar to the gully wind are reported from many areas of Australia, including the Northern Flinders Ranges, the Alice Springs area, the Stirling Range area near Perth and the Gammon Ranges in far north-west South Australia. Similar winds have been noted north of Adelaide in the Barossa Valley, and south to the Cape Jervis area (Holton and Grace, 1988b).

Summary

The Adelaide gully wind is postulated to be formed by gravitational acceleration of cool dense boundary layer air as it descends the lee slope of the Mt.lofty Ranges. The amount of coolness relative to environmental air at the same altitude over the lee plains (Delta T) will, in conjunction with the geostrophic synoptic wind strength, determine the ensuing gully wind strength. Severe gully wind situations will occur with large Delta T and strong easterly geostrophic flow.

Hydraulic jump formation accompanying the gully wind flow often moves backwards and forwards over the Adelaide foothills and plains in response to changes in Delta T and the geostrophic wind flow strength. This jump is the likely cause of "lulls" and "surges", and the rapid beginning and ending of most gully wind events. Rapid up and down motion on the jump are the likely cause of turbulence as reported by aircraft in the vicinity of the lee slopes and plains.

Acknowledgements

Thanks to Bob Manson for drafting, Fiona Hoad for word processing, Peter Webb for encouragement and Warwick Grace for his help in the production of this article.

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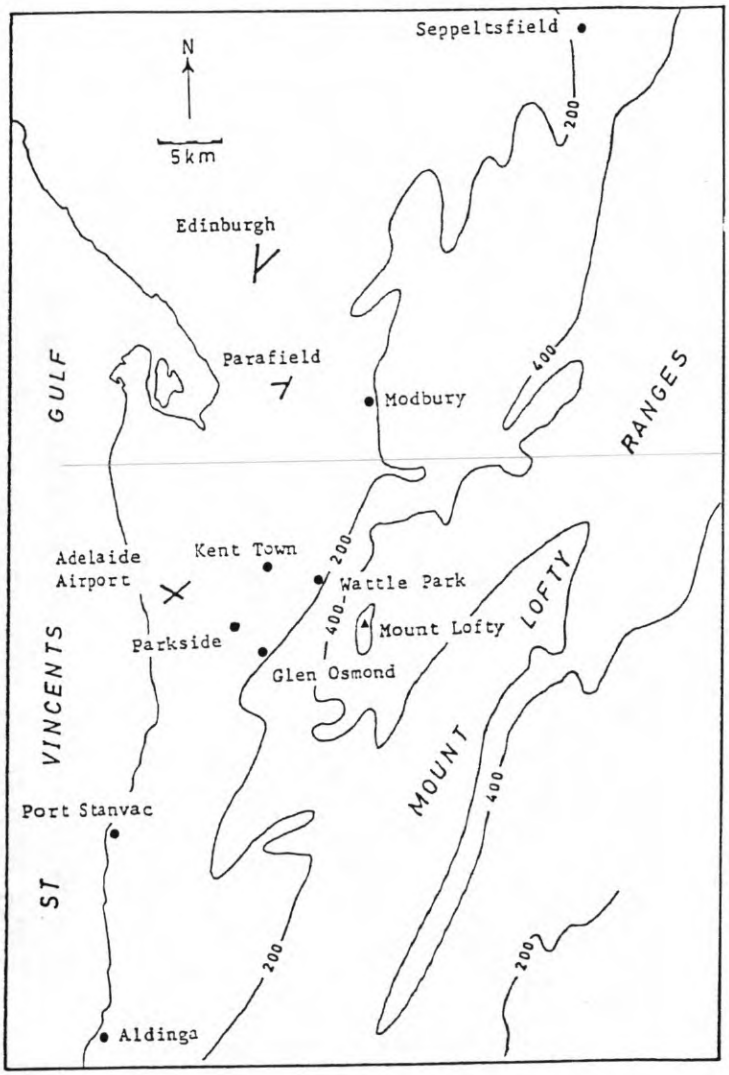


Fig. 1 Location Map

Overnight Wind Speed at Wattle Park for three nights with different Delta T

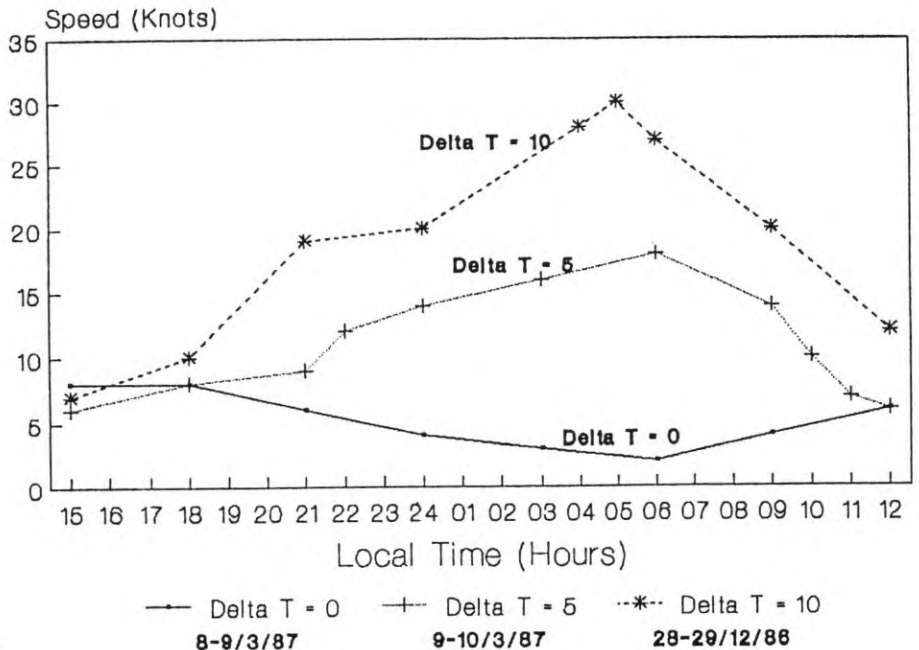
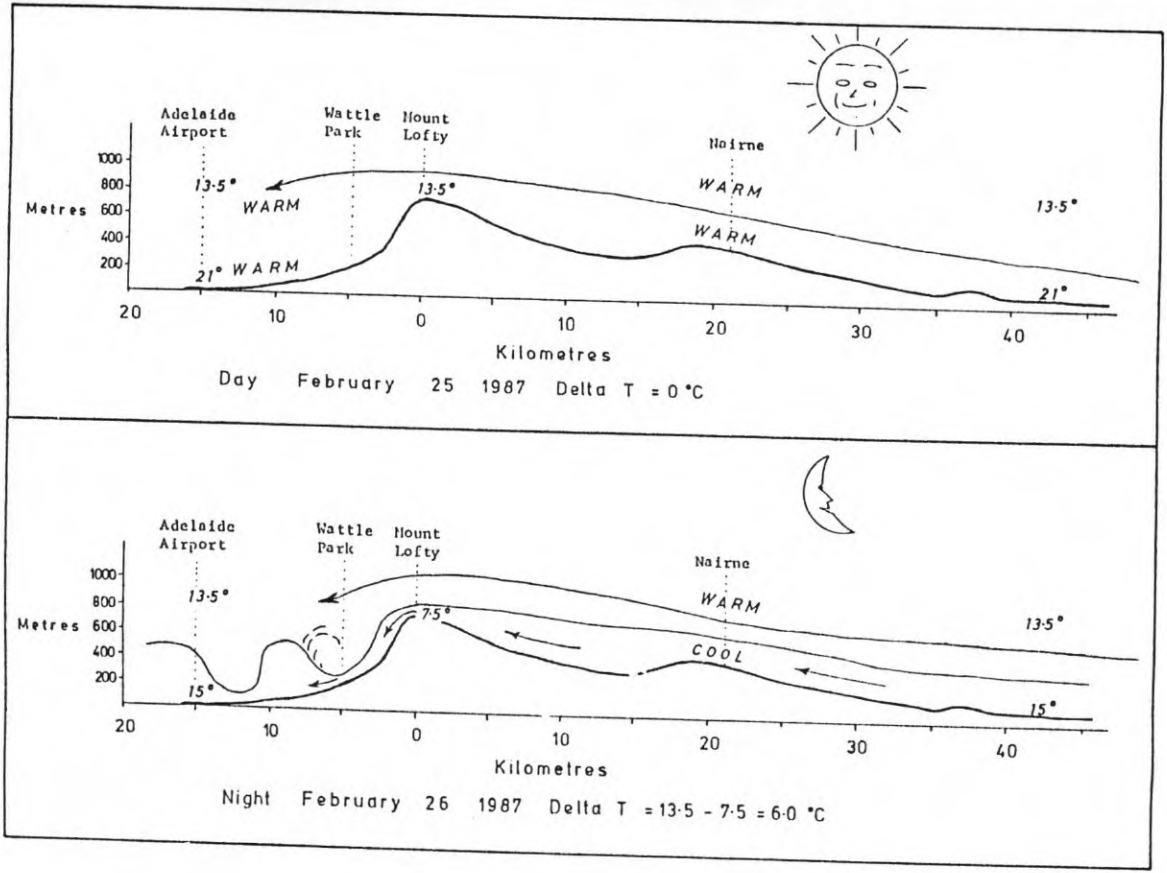


Fig. 3

Fig. 3

Fig. 4


Adelaide Airport
Wattle Park
Mount Lofty
Nairne
Metres
1000
800
600
400
200
13·5°
WARM
13·5°
WARM
WARM
13·5°
21° WARM
21°
20
10
0
10
20
30
40
Kilometres
Day February 25 1987 Delta T = 0 °C
Adelaide Airport
Wattle Park
Mount Lofty
Nairne
Metres
1000
800
600
400
200
13·5°
7·5°
WARM
13·5°
COOL
15°
15°
20
10
0
10
20
30
40
Kilometres
Night February 26 1987 Delta T = 13·5 - 7·5 = 6·0 °C

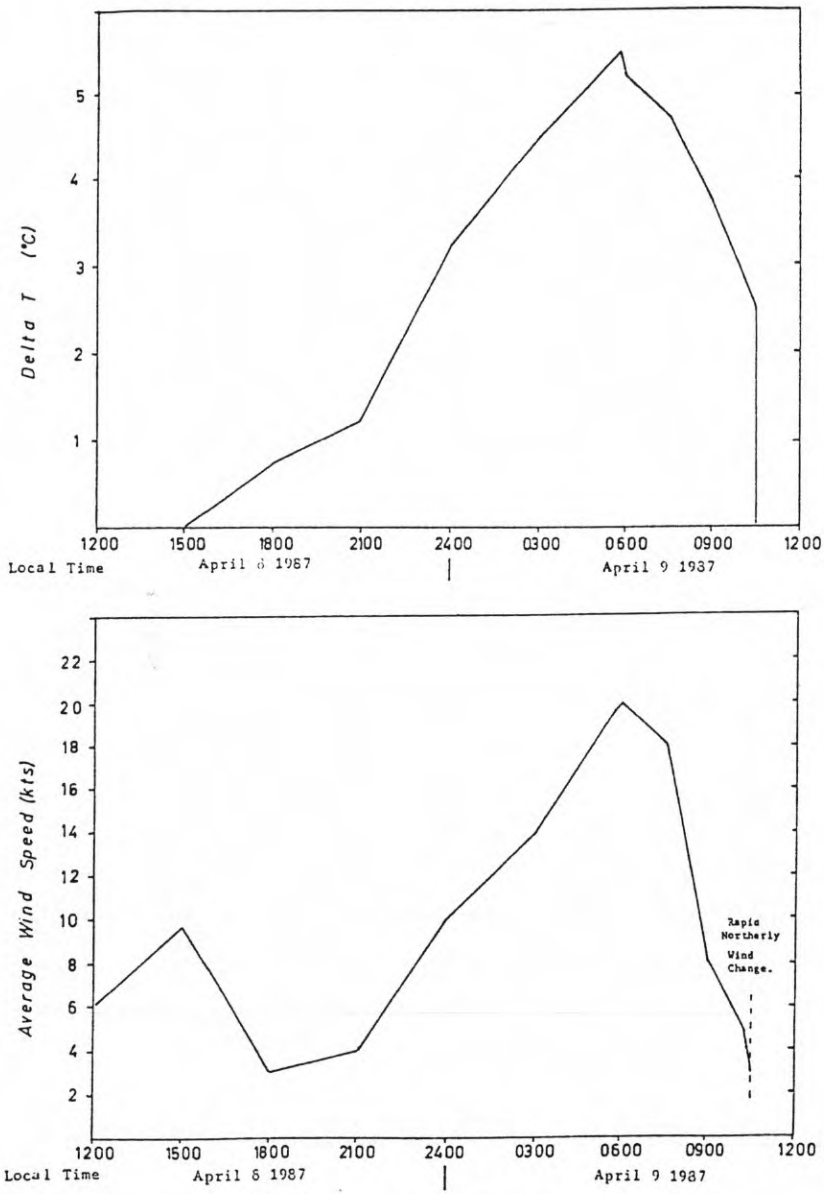


Fig. 2 Wattle Park Wind Speed Increase/decrease as Delta T incrwases and decreases during the night

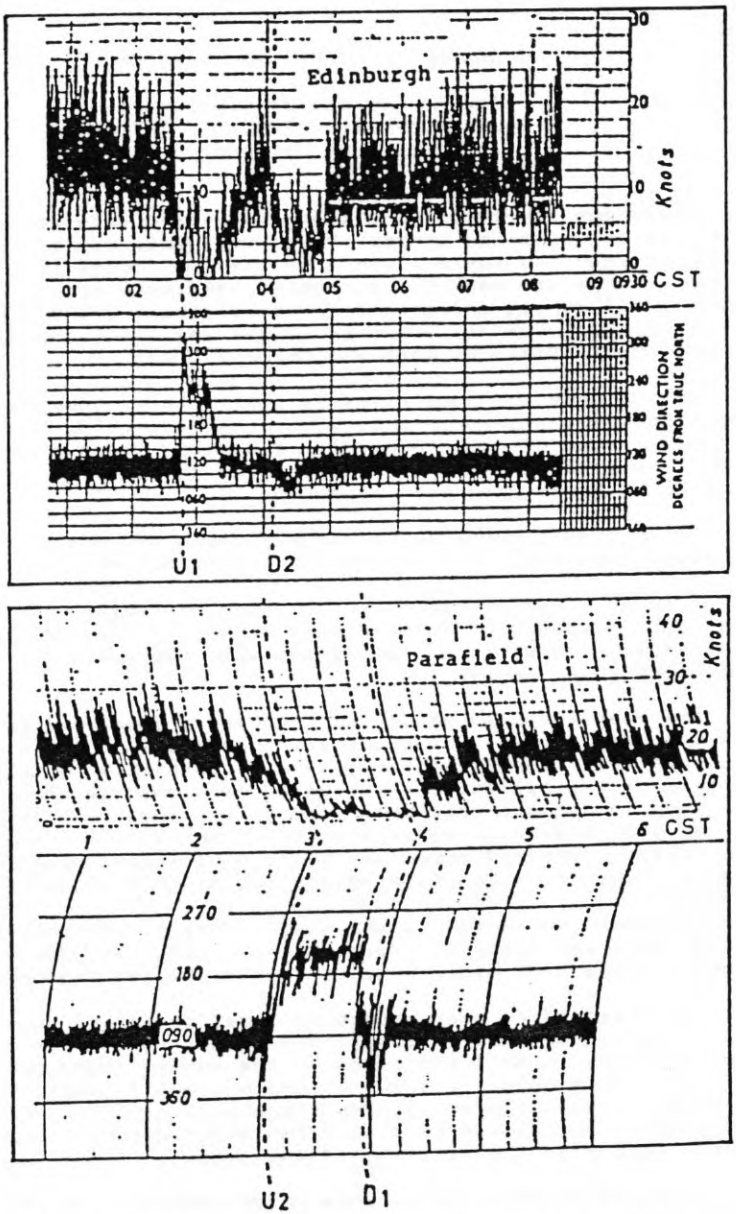


Fig. 5 Hydraulic Jump moving upstream and then downstream in gully wind flow

DOWNSLOPE WINDS AND AVIATION

Ian Holton and Warwick Grace
South Australian Regional Office
Bureau of Meteorology

Dangerous low-level wind shear and turbulence are often generated by downslope winds. Downslope winds may be defined as occurring when the surface winds on the lee foothills of a mountain range are markedly stronger than those occuring at the crest of the ranges and/or out on the plains. Downslope winds are associated with all mountain ranges and well-known examples are the Foehn, Bora, Mistral and Chinook winds.

In Adelaide the local term is gully winds: they occur predominantly on summer nights about the foothills. In the Flinders Ranges of South Australia downslope winds occur on either the eastern or western flanks; on the eastern slopes mean winds of 60 knots have been measured.

Associated phenomena such as lee waves and vortex shedding are also responsible for wind shear and turbulence.

Several theories have been advanced to explain the formation of downslope winds. These theories generally rely on various forms of wave theory or on analogues with hydraulic flow in laboratory experiments.

The most favoured mechanism involves a complex interaction of atmospheric waves; unfortunately this mechanism does not lend itself to real time forecasting. In this article we will use elements of the hydraulic analogue to help describe the wind shear and turbulence resulting from gully winds. It is probable that many of the features we describe occur at other downslope wind sites. Favoured sites are those with ramp-shaped ranges; that is, a gentle slope to windward but a steep slope to leeward.

The Adelaide region is shown at Figure 1. A cross-section through Adelaide Airport - Mount Lofty (along 110 /290) which is a common gully wind direction, is represented at Figure 2.

Many laboratory experiments to model downslope winds have been performed and one by Suzuki and Yabuki in 1956 is shown at Figures 3 and 4. Note the bulge in the denser fluid out over the 'plains'. This bulge is known as the hydraulic jump. At the interface between the two fluids there will be the equivalent of wind shear. Turbulence is also often associated with strong up or down motion in the vicinity of the jump.

Areas of observed turbulence or windshear occurring in gully wind situations are shown in Figures 5, 6 and 7.

Nearly three quarters of all aircraft reports of turbulence in the vicinity of Adelaide Airport have occurred during gully wind instances. Some examples are:

Case 1: Twin engined Cessna on eastern approach reported moderate to severe turbulence from ground level to 3500 feet. Virtually simultaneously, Argosy cargo plane on western approach experienced no turbulence but very gusty on landing. (This indicates that the Argosy was west of the hydraulic jump).

Case 2: Three light aircraft reported severe turbulence on descent at 2 to 10 miles south east.

Case 3: Navajo PA31 reported severe turbulence at 2000 feet at 4 miles south east. ("worst I've ever experienced").

Case 4: Twin engined Cessna reported "very severe turbulence" between 1200 and 4300 feet to south east.

Case 5: Two 727's reported severe turbulence - airport closed.

Of special interest to the Adelaide region is that the degree of turbulence is related to "delta T" (see Table 1) where delta T is the temperature difference between points A and B in Figure 2. The temperature at point B is known from the Mount Lofty automatic weather station on demand, and the temperature at point A is known from radio sonde balloon flights from Adelaide Airport.

Degree of Turbulence	Average delta T	Cases
Very severe	8.3 C	5
Severe	6.4 C	20
Moderate	5.3 C	20
Light or Nil	2.2 C	12

Table 1. Turbulence related to delta T - for the period November 1968 to April 1988 near Adelaide.

Further, it was found that only a few per cent of turbulence reports were associated with a delta T value less than 3 C. (The category of very severe was used if the pilot indicated "extreme", "pure terror", "worst ever", etc.).

There are theoretical indications and observational evidence that as delta T increases so too does downslope wind and the strength of the jump (and therefore the expected wind shear and turbulence) and that the jump moves further downstream.

Little hard data on the structure and position of the jump is available. However, Mr Nick Bell often flies in the Adelaide area on summer nights during gully wind situations - his Cessna 172 tows an illuminated advertising banner - and his observations

form the basis of Figure 7. Mr Bell also comments that there is commonly 300 - 400 feet "instantaneous" lift or drop at altitude 1500 - 2000 feet in the area just east of Adelaide's city centre. This area is described as having severe turbulence on Figure 7. These areas of turbulence are closely related to the position of the jump. They are, of course, average positions only.

The jump is not necessarily stationary but may move either up or downstream. The upstream-moving jump is usually stronger. At surface level this movement may be discerned from the behaviour of the wind. The rapid change in surface wind speed and direction is an indication of windshear associated with the jump.

Anemograph traces at Figure 8 show a jump moving upstream from Edinburgh to Parafield and then returning a short time later. Where the jump first moves upstream through Edinburgh and Parafield it is denoted U1 and U2 respectively; D1 and D2 denote where the jump first moves downstream through the stations.

Obviously the depth of the downslope wind is difficult to ascertain. Nevertheless, based on acoustic sounder studies at Salisbury, near Parafield, it appears that upstream of the jump it is probably only a few hundred feet.

Supporting evidence was obtained from Mr Alan Shore of Balloon Adventures Pty Ltd. Piloting a hot air ballon, Mr Shore has often encountered early morning downslope winds in the Barossa Valley to the north of Adelaide. Because the relief around the Barossa Valley is less pronounced than that around Adelaide, these winds are probably weaker than the Adelaide gully winds. Mr Shore noted that on descent through smooth, slow moving air, a sudden change to turbulent, fast westward-moving air occurs at about 200 to 300 feet.

Figures 5, 6 and 7 show favoured areas of turbulence and wind shear and the obvious lesson is that encounters with downslope wind-induced turbulence and wind shear will be minimised by avoiding lee slopes and foothills especially. For the Adelaide area, delta T and other parameters are being investigated for use in short-term forecasts of windshear and turbulence.

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POSTCRIPT

In October 1988, a field study of similar winds at Alice Springs in the lee of the McDonnel Ranges was conducted. Despite warnings, a hot air balloon carrying tourists was caught in the jump. Luckily, only bruises and broken limbs resulted.

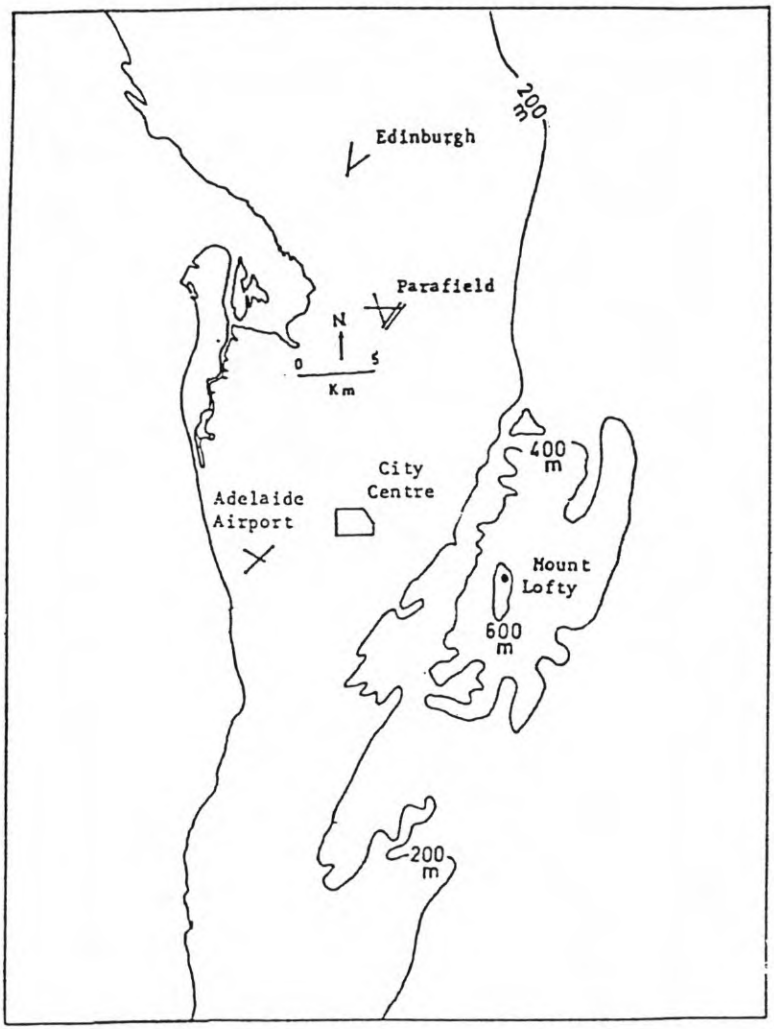

Fig. 1 Map of the Adelaide region. Mount Lofty is the highest point.

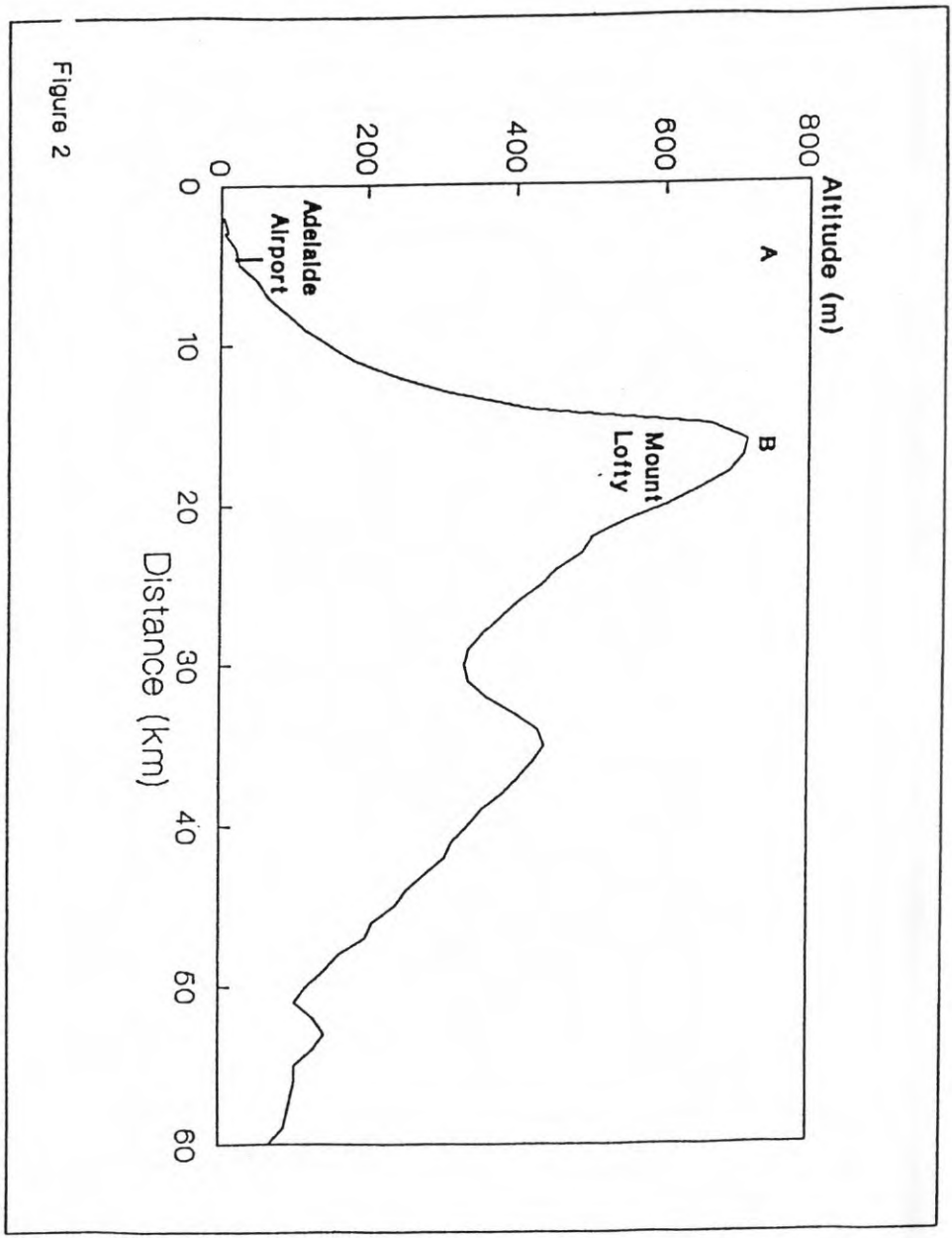

Figure 2

Fig. 2 Topographic cross section of the Mount Lofty ranges along 110 /290 . Point A is directly above Adelaide Airport and at the same altitude as Point B at Mount Lofty Summit. The vertical scale is grossly exaggerated.

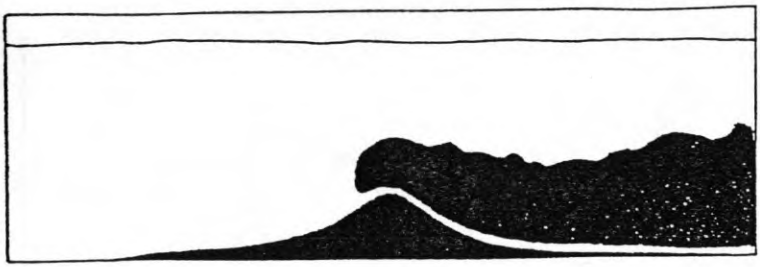

Fig. 3 Suzuki and Yabuki's laboratory experiment. The denser saline water (dyed black) begins to stream over a model hill in (clear) water at rest.

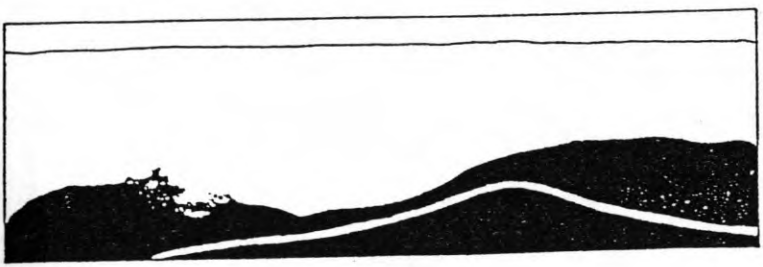

Fig. 4 As for Figure 3 but a short time later. The denser saline water reaches the plains and then 'backs up' to form a hydraulic jump.

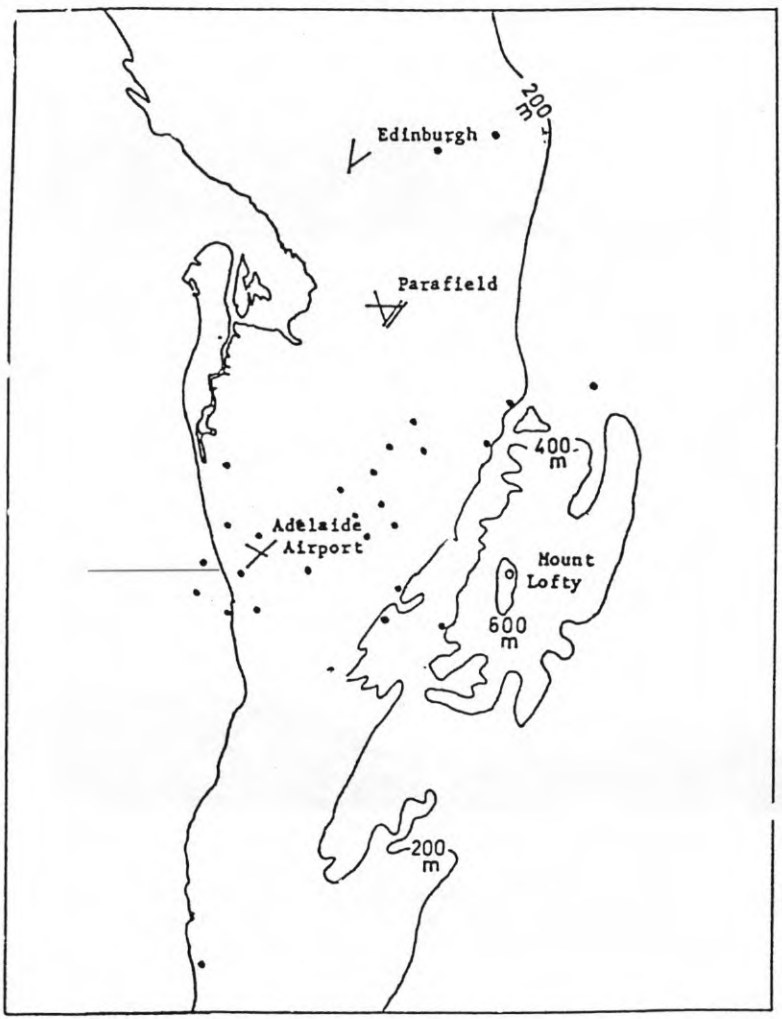

Fig. 5 Map showing locations of moderate turbulence or windshear. The locations are strongly biased to air traffic paths.

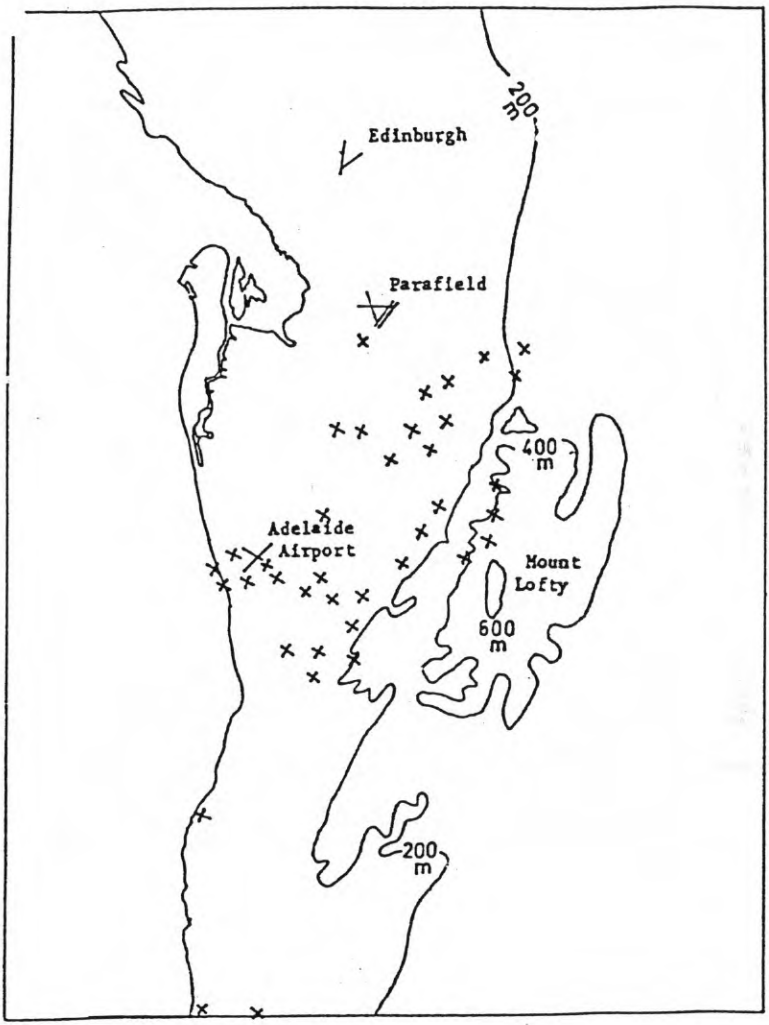

Fig. 6 As for Figure 5 but for severe turbulence or wind shear.

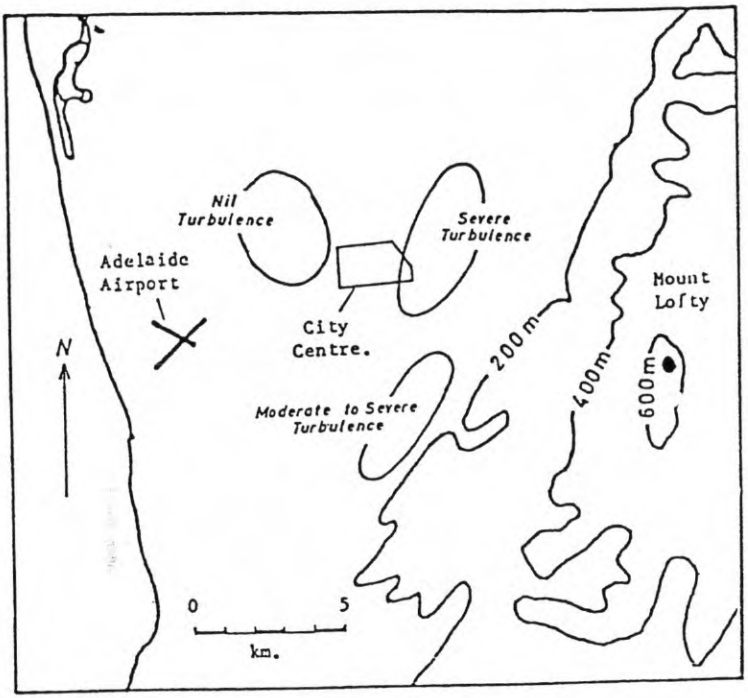

Fig. 7 Typical turbulence areas around Adelaide in gully wind situations as reported by Mr Nick Bell, flying a Cessna 172.

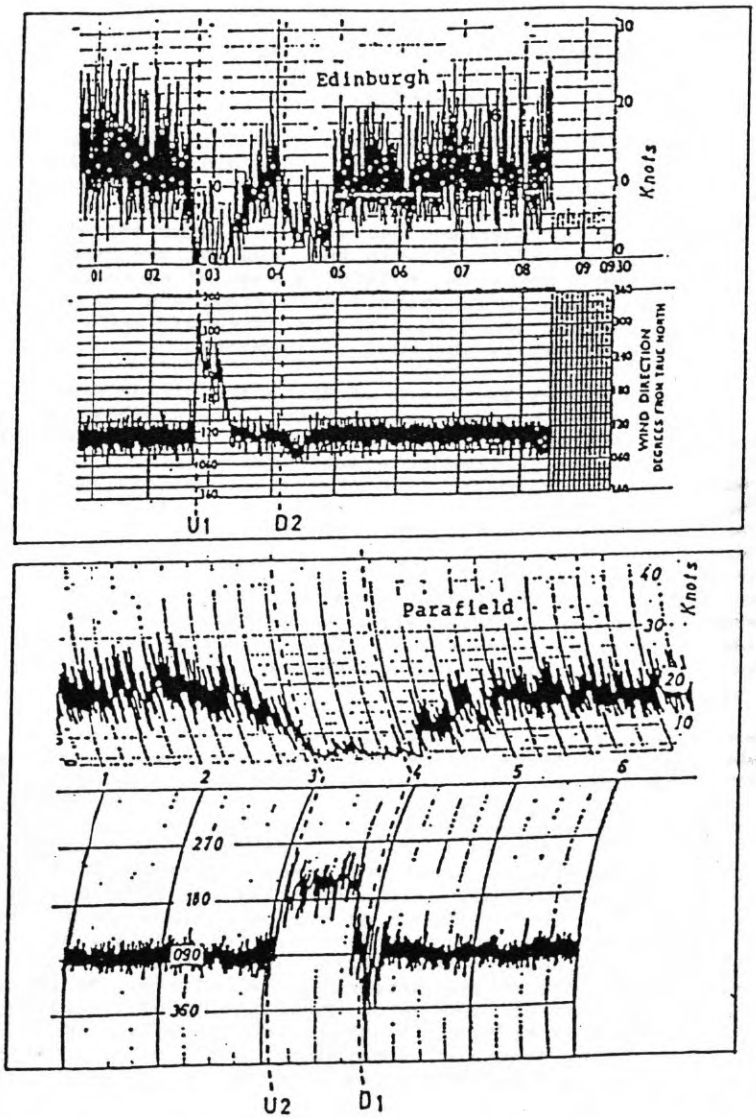

Fig. 8 Anemograph traces from Edinburgh and Parafield showing hydraulic jumps moving upstream (to east) and then returning a short time later.

THE FLIGHT OF THE AIRSHIP, R101

Adrian Gordon

The planned flight of the airship R101 from its base at Cardington, 50 miles north of London, to Karachi, which was then part of British India, was the culmination of an ambitious program intended to put Great Britain in the position of leader in the development of international airship routes and establish a rapid means of communication with the jewel of the Empire. The Btitish government's position in 1930, a year of economic depression, was weak. It was barely surviving, and any grandiose scheme, if successful, would take the pressure off and lessen the probability of a defeat in the House of Commons.

Lord Thompson, the Secretary of State for Air in Ramsay McDonald's Labour government, was acutely aware of this, and used his power and position to force the project through prematurely. But there was more to it than pure political ambition, even though he had been tipped for appointment as the next Viceroy of India; he was a personal friend of the prime minister who was highly dependent on his knowledge and expertise in the administration of his department. And what was for him perhaps the most important thing of all - he was deeply in love with and no doubt flattered by the attention of a Roumanian princess, and this affair more than anything else drove him to throw caution to the winds in order to impress her. This is a common failing no doubt in one in love, but in this case the lives of 53 others were involved.

On the face of it, considerable care had been taken to involve meteorological reporting and prediction; more than had ever been done before. Maurice Giblett had been working on the weather conditions related to airship flights for some years. In particular, he was assigned to participate in the flight, to receive weather reports and forecasts from Cardington as far as Marseilles, and to plot, analyse and prepare synoptic weather maps. On the basis of these, he was to brief the airship captain, the navigation and first officers on the conditions prevailing and to be expected along the flight path. Prior to the start of the flight he had access to the entire observational and forecasting facilities of the meteorological office. No amount of eulogizing about their deaths or whitewashing of the mishap in terms of patriotic sacrifices for their country will ever hide the conclusion that, from a meteorological point of view, there was no excuse for permitting the disaster and for so many lives to be lost in vain.

The flight was the first full test of air navigation aided by a comprehensive organisation for providing a meteorological service while in flight. It was basically experimental, with a new airship over new territory. By a strange irony of fate, on the very day when the news of the disaster broke in the London newspapers, Monday 6 October 1930, an item appeared in the

"Times" concerning the Annual Report of the Meteorological Office for the year ending 31 March 1930. The final paragraph stated, "close cooperation between the Meteorological staff and the airship personnel during airship operations had been the subject of much study and organisation. The staff of the Meteorological Office at Cardington had also studied the problem of forecasting along the various routes to be followed by the airship."

But the details of the tragic and fatal sequence of events which occurred cannot all be blamed on Lord Thompson, who had to be back in London by 20 October in order to attend the forthcoming Dominion Conference at the specific request of Ramsay McDonald. He would have preferred to have left Cardington on Friday evening or Saturday morning rather than the planned Saturday evening. Either of these earlier times of leaving would probably have led to a successful outcome.

There were other actors too in the drama. It was Wing Commander Colmore, Director of Airship Development who objected to the earlier start, and not on the grounds of weather, which he scarcely considered. His reasons were that the crew wouldn't have time to get the rest they needed before starting on such a long journey and that a morning start would mean arrival at Ismailia in Egypt at an inconvenient time for landing. He wanted the landing to take place a little after sunset when the cool of the evening would give the advantage of extra lift. But there is no reference to any advice from Maurice Giblett on this point concerning the hypothetical difference in lift between a little after sunset or sunrise. In fact if Colmore's reasons are examined more closely, particularly the lift consideration for mooring, they tend to lose their validity. It seems more likely that the shy and aloof Colmore had his own personal reasons for delaying the start until Saturday evening. But his views passed unquestioned and were approved by Lord Thompson upon whose decision the final go-ahead rested.

And so Saturday evening 3 October it was - and what about the weather?

The previous day, Friday, had been most deceptive. The maximum temperature in London had been 20 deg C (68 deg F), giving a false impression that Summer was lingering on, yet in less than 36 hours the situation had transformed into a quite severe frontal trough moving eastwards from the Atlantic and bringing a rapidly falling barometer, strong winds and continuous rain.

At 0930 on 4 October, some nine and a half hours before takeoff, Major Scott, Assistant Director of Airship (Flying and Training), had been present with Giblett and the relatively young captain of the R101, Flight Lieutenant Irwin, at a weather conference in the Met.Office forecast room at Cardington. They went over the charts. The main identifiable features at the time were weak and moving asway to the east. But ominous signs of

unsettled conditions approaching the west coast of Ireland from the Atlantic seemed to pass unnoticed. It was thought that by nightfall the winds over northern France were likely to be of moderate strength from west to southwest with fair weather extending over southern France and the Mediterranean. "It should be alright" was the consensus.

The weather can in some of its characteristics be likened to sickness and good health. A storm may form rapidly and die away equally fast, as a sudden fever may develop and pass away overnight, or there may be a gradual, almost unnoticeable covering of the sky and a slow thickening of cloud which continues for many hours before the first raindrops fall. But once such unsettled and stormy conditions have become well organised, like a virus infecting the human body, they become established and may persist at length before slowly recovering to the original state. To some extent this was what was about to happen on 4 and 5 October 1930.

Of the three persons attending the 0930 weather conference on that morning Scott was by far the most vocal and dominant and it would have been his view which would have prevailed over those of the young captain and his meteorologist. Scott's personality emerges as wholly arrogant and foolhardy with a reputation of wanting to press on, often regardless of the consequences. A little earlier in the planning stages he had vehemently laid down his interpretation of things.

"I am the officer in command of the flight. I decide such matters as when the ship shall depart, her course, speed and the height at which she shall fly. The captain of the ship commands the crew, and he is responsible for discipline, and responsible too for carrying out my orders."

Whether there was any authority for such a claim is not known; it could have been the result of a paranoic delusion. In any case, the state of affairs was not clearly spelled out. As for Scott, it had been said of him by a colleague that his failure to deal with problems adequately showed how greatly his effective understanding and determination had deteriorated. And this was the man to whom Giblett the meteorologist had to face up in advising caution on weather grounds.

And what of Maurice Giblett? The key to the whole tragedy could rest in his hands. But meteorologists have rarely possessed the aggressive personalities or the rank of the military or of those civilians with a military background with whom they have had to deal.

Later in the day of 4 October Major Scott was met in the administrative block at Cardington by Colemore and Giblett with a later and less favourable forecast extending up to 0100 the next day. This forecast now pinpointed the less ominous signs of the earlier one. A trough of low pressure over western Ireland was spreading in quickly, with southwesterly headwinds freshening up

to 20 -30 mph later over northern France at 2000 ft, the approximate flying level of the craft. Weather would be fair at first with rain later. But Scott, with his customary blustering impatience said,

"The glass is falling. I want to get all stores and possessions aboard as early as possible, so that we can get away before the rain starts and in case the wind does get up a bit."

Although the more cautious Colemore is reported to have been thoroughly satisfied with the conditions along the route there is no mention in any of the references to the subject of the opinions held or expressed by Maurice Giblett, a professional and expert in weather science.

On his way to Cardington, Lord Thompson himself had access to the latest forecast issued at 1220 which said again that a depression in the eastern Atlantic was spreading east bringing winds from the southwest of moderate strength over northern France and mainly cloudy weather. Rain was not mentioned in this version of the forecast, but it was probably of earlier origin than the one Giblett and Colemore had shown to Scott at Cardington. Weather balloons were let off twenty minutes before the departure and these confirmed that the upper winds were slowly increasing. They had now reached 24 mph at all levels up to 2000 ft. The sky was overcast and a spitting of rain could be felt.

A few of the crew had grumbled at this stage, muttering that it was not the best of evenings on which to be setting out. Rain was clearly "blowing up", to use a layman's term, and the wind was rising too. Yet, it would be a great loss of face to put off the flight now, with so many distinguished passengers aboard. Furthermore, it was the official view that airships had to show that they were not just good-weather craft. All at Cardington were agreed that the time was overdue when the R101 should show what it could do.

And so Lord Thompson, his aides, his valet, his heavy ceremonial sword, his red "carpet" weighing 129 pounds, his 254 pounds of personal baggage and two crates of champagne were loaded aboard.

Take-off occurred soon after 1800, but it was 1830 before they had circuited Cardington and headed South.

At 2030, two hours later, Cardington transmitted an updated forecast for the flight path for the next 12 hours. The truly ominous nature of the conditions, which had now begun to affect the airship itself could no longer be overlooked. The prediction was for steadily worsening conditions up to and beyond Central France. Surely if this forecast had been available three hours earlier the start would have been postponed? In detail, near head-winds of 40-50 mph were predicted, accompanied by much low cloud and continuous rain.

When this forecast would have been received, just over two hours out, in retrospect a return to base would have seemed the sensible thing to do. What was Giblett advising? Was there a weather conference at this time? And if so, did the "press on regardless" tactics of Scott prevail? Or were those who had the responsibility and power to make the vital decision having their dinner in the dining room, perhaps toasting themselves with champagne?

The ship sailed sublimely on, always at a rather low altitude. One of the survivors of the crew estimated the height over the Channel to be 800 feet. The hourly log of observations transmitted to base gave the minumum height of flight as 1000 feet, even though reports from observers on the ground nearly all said that it was flying very low. This was particularly true near Beauvais where some inhabitants later attested that the airship had practically scraped the roof of the cathedral, some 50 metres above the floor!

There could have been several reasons why the R101 was flying low. Perhaps it could just not gain altitude in the stormy conditions prevailing. Perhaps it was following the cloud base so that the captain and navigator could maintain visual contact with the ground. The cloud ceiling was continually getting lower as the rain persisted and saturated the air below it. Then, of course, there could have been errors in the calculation of the height by means of the barometric pressure readings. Atmospheric pressure was falling very fast, as much as 5 millibars during the last three hours up to 0100. If Giblett had been paying close attention to the wireless transmissions from Cardington he would have noticed this. A fall of barometric pressure of 5 millibars, not taken into account in height calculations from the ship's altimeter reading would lead to an overestimate of some 150 feet in the computed height of the ship above ground. But perhaps Giblett was dining with the VIPs. Whatever took place, no sign of any foreboding was contained in the routine messages sent by wireless to base. At midnight, Captain Irwin informed base that all was well and that the party had dined well, smoked their cigars and was now turning in for the night.

At 0200, seven minutes before the final and near instantaneous catastrophe, coming up to Beauvais almost head to wind through bursts of heavy rain with ground speed less than 22 mph and the wind in fierce gusts, the final routine hourly report was made: Wind speed 225 degrees at 50 mph, cloud base 1200 feet and elevation 1200 feet, the latter figure hardly in agreement with ground reports that the ship was flying very low over Beauvais and seeming to be in trouble.

Something else of great importance also happened at 0200. There was a change of watch in the flight cabin. Captain Irwin was quite exhausted after eighteen hours of continuous hard work

and responsibility. He had piloted the ship safely so far. He and his first officer were now replaced by Flying Officer Steff, the second officer, and Petty Officer Hurst. On elevations was a new member, Mason, a person who was known to tend to let the ship gradually lose height.

And so, at the most crucial time of the whole flight, when the trough of low pressure and its cold front were getting quite close - in effect, one reason for the bad weather lasting for such a long time was that the airship was flying always a little ahead of the trough, a kind of race with both travelling ion the same general direction - at that very time, almost everyone had gone to bed and the vessel was left in the charge of the least experienced and most junior personnel of the whole complement.

At 0207 on the morning of Sunday 5 October 1930, the R101 hit the edge of a wood on the 100 metre contour with rising ground ahead. It instantly burst into an inferno of fire as the inflammable hydrogen gas exploded. Forty-six persons were killed outright, two more died a few days later in hospital, and six survived with burns of varying degrees of severity.

Numerous theories and reasons have been put forward concerning the cause of the crash. There is probably no single main reason but rather several contributing factors. Indeed, it would be futile to try to pinpoint one sole cause. There were too many possibilities. The weather certainly played a very important part in the affair.

Its effects can be summarised:

1. The strong headwind component meant that the ship was travelling slowly, probably at a speed less than that of the low pressure trough that was tracking it.
2. The continuous pouring rain would have clung to the vast envelope of the dirigible and weighed it down beyond its capacity.
3. The strong winds in the frictional boundary layer, blowing over woods and undulating hills and valleys would have created rough turbulence which could have made the ship unstable.
4. In addition, the ship could have been caught in a down-current lee wave as the wind upstream crossed the tail end of the so-called Beauvais ridge. Ahead of the flight path and upwind, the ridge dropped towards the R101 from 150 to 100 metres. Further to the west the ridge dropped on its southern side from 170 to 90 metres in a short distance.

The weather situation prevailing immediately prior to and during the flight is reconstructed in Figures 1 - 4.

Figures 1 and 2 show the weather maps for 0700 and 1800 GMT, 11 hours prior to, and the hour of departure, respectively. Charts such as these were published by the Meteorological Office a few days in arrears and they provide a guide to the information available. Upper air charts like the ones that we have today

were not available, nor were fronts separating warm and cold air masses included. These have been inserted by the author.

On the morning chart, 11 hours before takeoff, there is strong evidence of a young and fast-developing secondary depression to the west of Ireland moving north-east. The small depression over Yorkshire is innocuous and moving away to the east. By 1300 (1.00 p.m.), rain had spread across much of Ireland with winds up to force 6 on the Beaufort scale along the west coast and the barometer falling at the rate of 4 millibars per 3 hours. By takeoff, 1800 (6.00 p.m.), the belt of continuous rain had spread into western England.

Figure 3 shows the chart for 0100 on the following day, 5 October, just one hour before the crash. The point of occlusion where warm and cold fronts meet is now in the English Channel. Evidence of this is given by the fact that the largest barometric fall of 6 millibars in the previous 3 hours were reported on the south-east coast of Kent. Gale winds from the west south-west were reported along the entire south coast with a full force 8 gale at Portland Bill and a force 9 gale at Brest onn the coast of Brittany. Paris itself, not shown, but some 80 kilometres south of Beauvais, reported a force 8 gale. The pressure there had fallen 8 millibars in 7 hours. The tightest pressure gradient and therefore wind speeds were found in a belt extending from the south coast of England to Paris. A reasonable explanation of these reports could be that a small but vigorous disturbance formed at the point of occlusion and this travelled up the English Channel, hugging the sea from which it derived its energy.

Figure 4 shows the map for 0700 on the morning of 5 October. The storm had now vented its fury and calmed down to a more normal state. The wind at Paris was now only force 4.

So much for the weather itself. But adding to its dangers were the lack of awareness and action to counter those dangers, together with the total disinvolvement of all the experienced personnel. Tragically, this resulted in the ship being left in the hands of the less-experienced, if not incompetent crew mat the worst possible time, probably because it was night, and the more senior officers wanted to go to bed!

Photographs of the R101 taken after the crash, looked at in conjunction with a detailed ordnance map of the area, show that the burnt-out skeleton lay at a bearing of about 30 degrees, that is , facing west south-west across the northern edge of the wood, the bow in the wood, and the remainder in the adjoining field. If an extrapolation is made backwards, drawing a line along the backbone of the airship skeleton, it will be noted that the underlining topography during the approach to and passing of Beauvais was only some tens of metres less than the 100 metre contour at which impact with the ground was made. It just did not seem to be able to gain height. At that stage it was doomed.

The tail end of the Beauvais ridge reaches 150 metres directly on the ship's flight path.

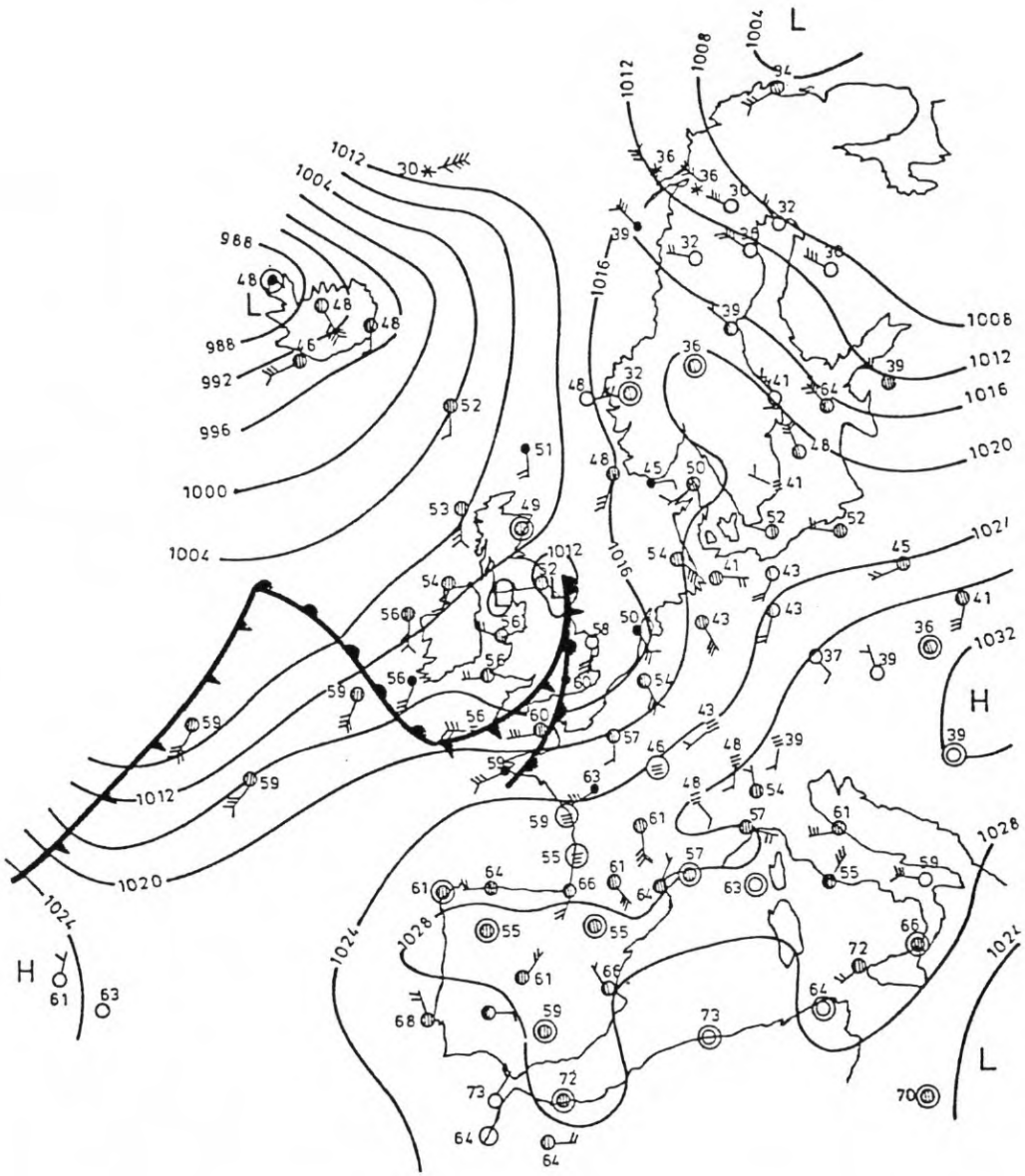

Fig. 1 Synoptic chart for 0700 GMT, 4 October 1930

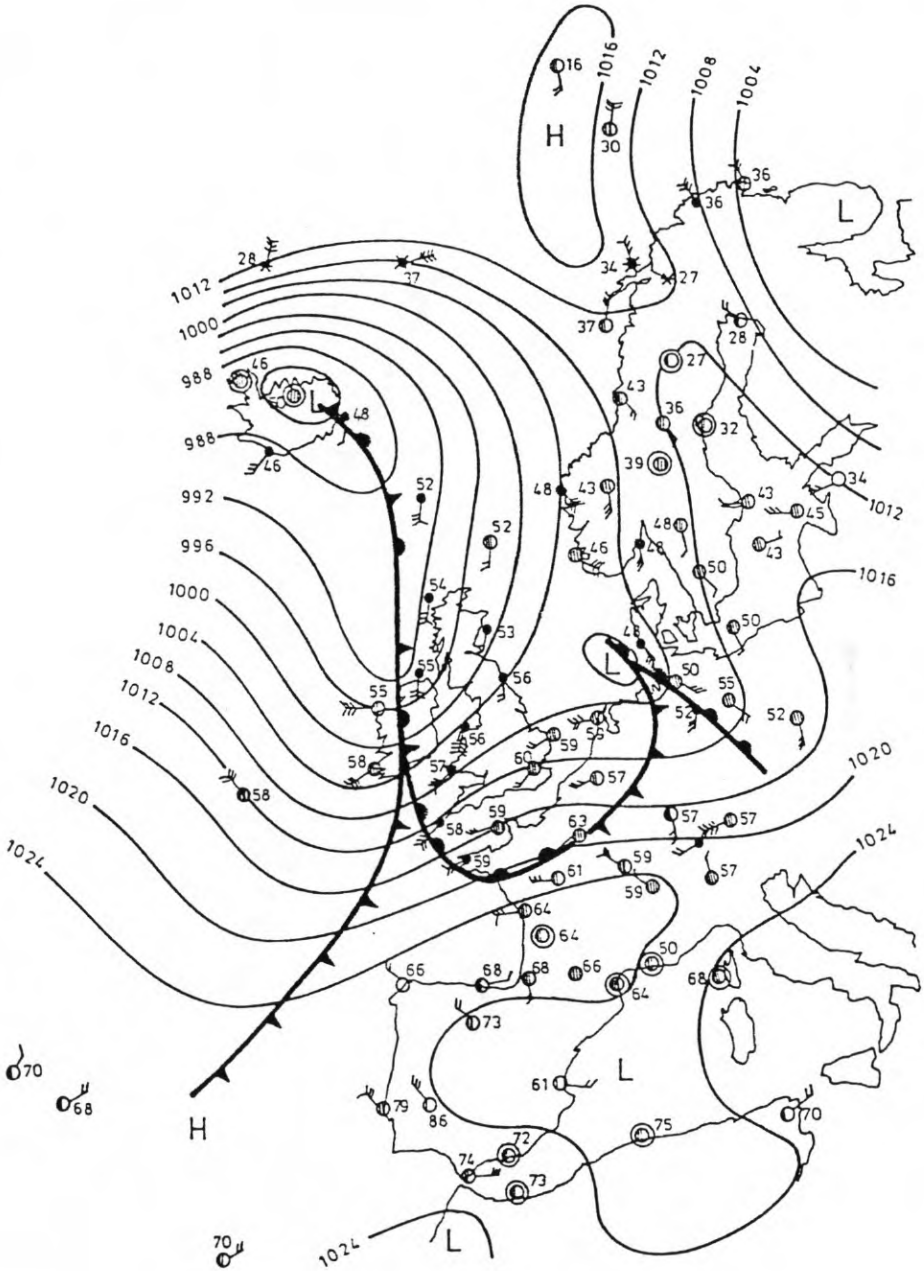

Fig. 2 Synoptic chart for 1800 GMT, 4 October 1930

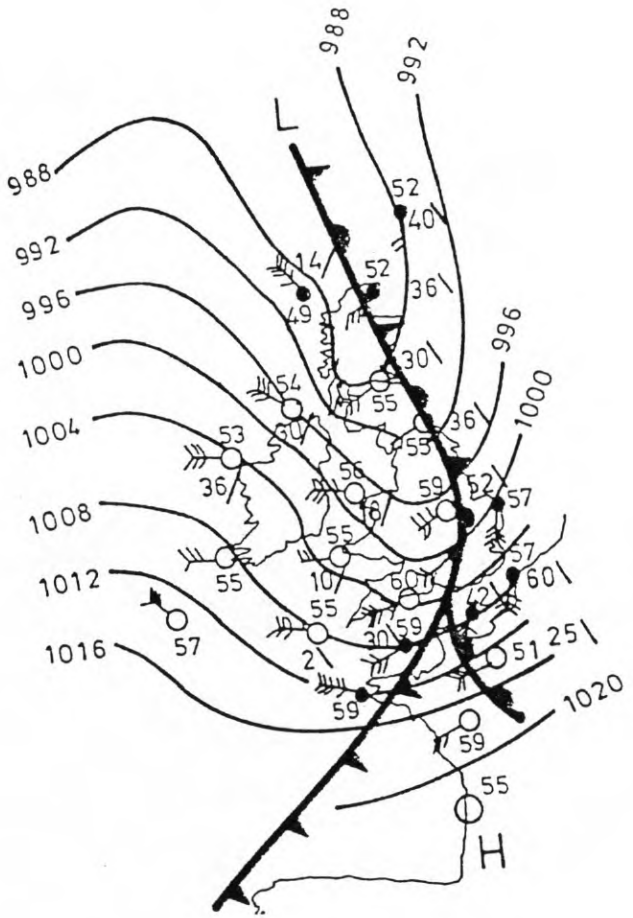

Fig. 3 Synoptic chart for 0100 GMT, 5 October 1930

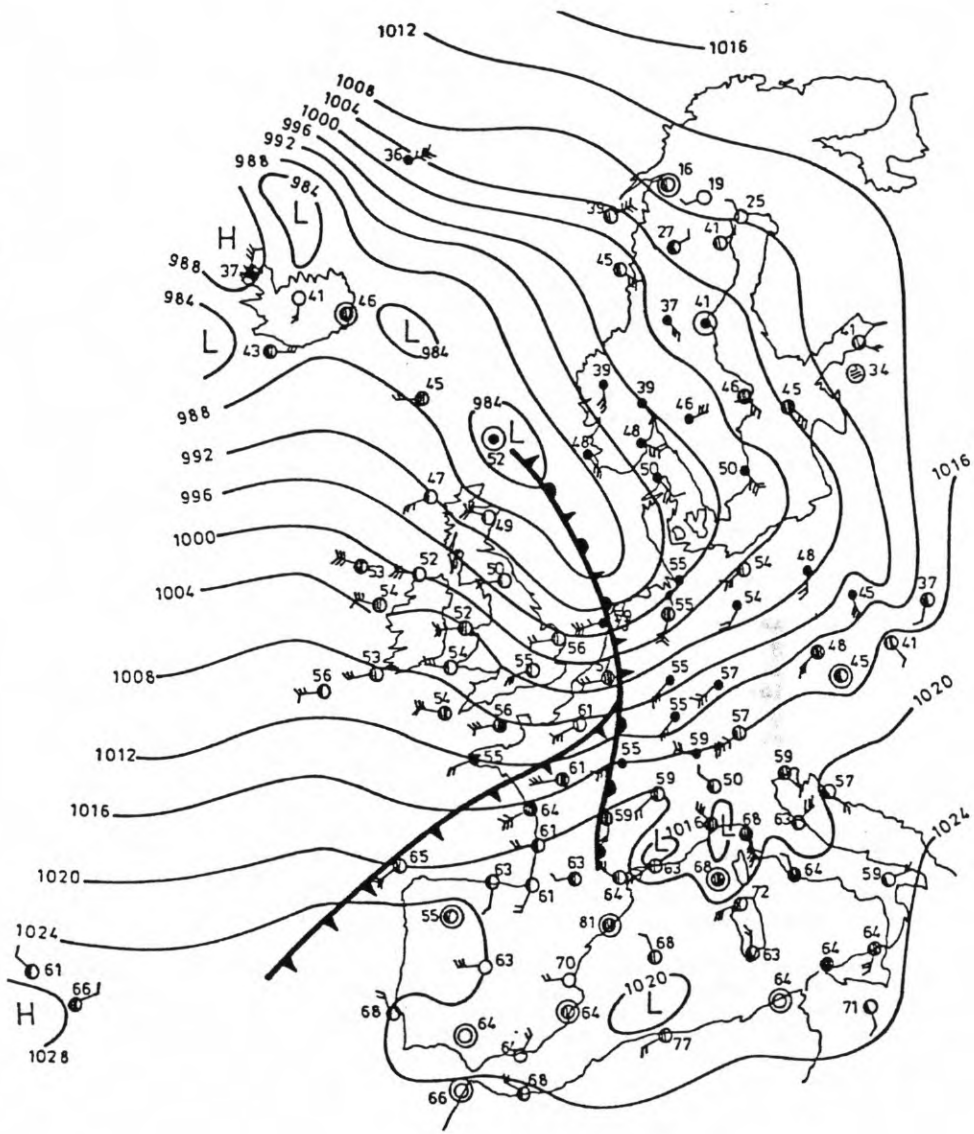

Fig. 4 Synoptic chart for 0700 GMT, 5 October 1930

STRANGE LIGHTS OVER THE NULLARBOR

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Quite a few unusual lights have been sighted over Australia's Nullarbor region, but none have received the notoriety of the two 1988 incidents. There are no towns of any size between Ceduna and Norseman or Kalgoorlie (see Fig.1); most are railway sidings or road settlements of just a few people. Although the Eyre Highway runs closer to the coast than the Nullarbor Plain itself, the whole area has come to be known as "The Nullarbor". Between Madura and Eucla, an area known locally as "The Basin", there is a line of 100m hills to the north, but east of Eucla the highway is located on higher ground.

It really is a perfect area for "UFO" spotting. The dry, desert conditions give rise to decreased cloudiness, there are no city lights to distract the spotter, road and rail traffic is fairly sparse and the horizons are flat and wide. There is an awesome splendour there about the night sky that has to be seen to be appreciated.

The first of the 1988 incidents occurred about 4.20 a.m. Central Daylight Saving Time (C.D.S.T.) on 20th January, when the Knowles family was travelling eastwards on the Eyre Highway. About 40km west of the Mundrabilla Roadhouse, they saw a light over the road ahead of them. At first they thought it was the light from a truck approaching them from the east, but it became bigger and brighter, frightening them into taking evasive action. The driver of the car said the light appeared and disappeared "after jumping about a bit". He described its shape as "like an egg in an eggcup and about one metre wide", and its colour as "bright and wide with a yellow centre". His sketch of its shape was included in newspaper articles. (See Fig.2)

There were other vehicles within 30 or 40km but the occupant of only one, a truck driven by Graham Henley, reported seeing any unusual light. He was driving east some distance ahead of the Knowles' vehicle and said he saw a light that was "too high up to be another truck or vehicle". It was "white and yellow in colour" and it "disappeared and re-appeared". The crew of a tuna boat fishing in the Bight waters "hundreds of kms away" also saw a strange light on the same night and it was elongated in the vertical, but no direction or elevation of this light was reported.

The Knowles family claimed that their car was picked up by the "UFO" and as it was dumped, a tyre burst. They also claimed that a black ash covered the car and that there were indentations on the car's roof. They drove off at high speed and were

obviously very distressed and somewhat hysterical when first interviewed.

Their vehicle was subjected to thorough inspections on several occasions by the police and various UFO research groups in Australia, but none of these inspections showed that there was anything unusual about the car. There was no black ash inside or outside the car; the only addition was a black deposit on the metal rims of the two front tyres, which was consistent with material from the brake linings. The rear right-hand tyre had burst in a normal manner, such as one might expect from a vehicle driven at high speed, leaving some rubber marks on the wheel arch. The dents on the roof of the car were insignificant and there was no proof that they had not been there before the event. So there was nothing mysterious, only the unusual eggshaped, white and yellow light that they saw.

The second incident occurred about 1 a.m. Central Standard Time (C.S.T.) 17th October 1988 in roughly the same area. There seems little doubt that the first incident helped to precipitate the second. A bus, driven by Mr Peter Chapman with 25 passengers on board, was travelling westward along the Eyre Highway about 20km west of the Mundrabilla Roadhouse. The driver saw a light on the right-hand (northern) side of the bus and woke five of the passengers who also saw the light.

Newspaper reports said that the driver was "terrified" but he evidently wasn't sufficiently terrified to waken the other twenty passengers sleeping in the bus. He didn't stop to observe the light, which he described as "a bright white light which appeared to be hovering about 20m above the ground and giving the impression that the light was moving". It was also reported that "the bright light followed the bus for about 10 miles as he travelled at high speed to escape".

One passenger said that she saw the light in the driver's mirror. She thought "it was the reflection of the headlights of a transport behind the coach". The highway tends slightly south of due west in this sector, and with comments like "on the right-hand side" and "in the rear vision mirror", it does seem that the most likely direction of the light was from the north-east. No unusual effects on the bus and no unusual marks on the ground were reported. Also there were no comments on the shape of the light, which the driver said "was not bright enough to illuminate the bus or the surroundings".

Investigation of the weather conditions prevailing at the time of these incidents showed that each was characterised by fairly cloudless and calm conditions, although such conditions resulted from different meteorological situations. In order to find a factor which might be common to both incidents, their salient features have been extracted and listed in Table 1 for comparison purposes. Apart from the fact that they both occurred on the Eyre Highway west of the Mundrabilla Roadhouse, there

seems to be nothing which one could say was definitely common to both incidents - that is, until the upper air temperature profiles are examined!

In each case, the nearest temperature sounding ,at Forrest, about 100km to the north, showed a marked temperature inversion, that is, warm air overlaying colder air. These soundings are shown in Figures 3a and 3b. Again, one can pick out differences in the two profiles, but the fact remains that on both occasions there were marked departures from the usual temperature decrease with height.

The meteorological situations are interesting. The surface weather chart for 6 a.m. C.D.S.T. 20th January 1988 (see Fig. 4) shows a pronounced ridge of high pressure extending along the whole of the southern coastline of W.A. from a High centred well west of Perth. This is quite unusual for a summer chart. The ridge was over 1000km in length, and as ridges are associated with subsiding air and increased stability, it is understandable that the Forrest inversion was not an isolated one. In fact, inversions were evident over the whole 1000km (plus) length of the ridge from Ceduna to the South-west corner of W.A., but they were much stronger along the coastline, for example at Esperance, where the inversion was 8 deg C.

The surface chart for 3 a.m. C.S.T. 17th October 1988 (see Fig. 5) is a little different. It shows a large high pressure area over the head of the Great Australian Bight, again with evidence for widespread inversions over the Bight area. All the evidence showed that the inversion at Forrest was representative of the area where the sighting took place.

The refractive properties of inversions have been described in many meteorological texts, but in view of the general lack of knowledge about meteorological optics, even amongst scientists, it would be appropriate to summarise what refraction does in the lower levels of the atmosphere.

We all know that light travels in straight lines providing that we are dealing with a homogeneous medium. For most of the time, the atmosphere acts as a homogeneous medium, but there are exceptions to this when sharp discontinuities in the vertical structure of the air cause aberrations of this straight line path. One of the main discontinuities is found in a pronounced temperature inversion, where there is a sharp density difference in the air above and below the inversion. This causes refraction and the path of light is bent downwards, giving the impression that the object seen is much higher than it really is.

For example, the wave fronts from a distant light source on the earth's surface (see Fig. 6) will be quite regular until the upper part of the wave front passes through the inversion. Here the temperature is higher, the speed of light is fractionally greater. and this part of the wave front is speeded up. Such a

TABLE 1

COMPARISON OF THE TWO 1988 INCIDENTS

Feature	The sighting of 20 January 1988	The sighting of 17 October 1988
Location	About 40km W of the Mundrabilla Roadhouse	About 20km W of the Mundrabilla Roadhouse
Time of Year	Summer	Winter
Direction of travel of the observers	East	West
Most likely bearing of the observed light	From the East	From the West
Shape of observed light	Elongated in the vertical	Not specified
Physical effects on vehicle	Observers claimed that their car was picked up. Also claimed a covering of black ash, burst tyre and roof indentations. These claims were not substantiated by inspection of car	None
Prevailing weather conditions	Strong high pressure area W of Perth. very pronounced ridge of high pressure along the whole southern coastline of W.A., extending as far east as Ceduna 0-2 eighths low cloud, very light winds.	High pressure area over the head of the Bight. Almost cloudless 1-2 eighths high cloud Very light winds, eg., Forrest E 2 knots
Upper air temperature soundings	Temperature inversion at Forrest 3800 to 5300 ft. approx. 5 deg C. Greatest increase in temperature near the top of the inversion layer. Stronger inversion in the ridge of high pressure along the coast, eg., Esperance 8 deg C.	Marked temperature inversion 1000-1400 ft about 8 deg C at Forrest. Greatest change of temperature near the bottom of the inversion layer.

distorted wave front (upper part speeded up, lower part retarded) may reach an observer in a suitable position and his eyes see an image (normal to the wave front) in a position which is well above where the surface light source actually is. Such an image is known as a "superior image".

The Glossary of Meteorology defines a mirage as "a refraction phenomenon wherein an image of some object is made to appear displaced from its true position". The key word is "displaced", but it is important to realise that distortion of shape, colour, size and intensity also occur. These distortions obviously make identification of the object more difficult.

Even under the most steady meteorological conditions with a simple temperature profile, when it is possible to see a good identifiable mirage for many minutes, it should be stressed that the air is moving and the path taken by the light reaching the observer's eyes is subject to changing meteorological conditions. When the temperature profile is more complex, multiple images may occur, some in grossly distorted forms with unusual colouring. Some of the distorted forms can fool even those quite used to the characteristics of refracted images.

The most common forms of distortion (see Humphreys, 1929) are:

(a) Towering. This is an apparent vertical stretching which occurs when there is an increase of refraction with height within the inversion layer. The inversion on 20th January was of this type.

(b) Stooping. This is an apparent vertical shrinking which occurs when there is a decrease of refraction with height within the inversion layer. Under these conditions, spherical objects take on the appearance of disc-like "flying saucers".

(c) Inverted images. These occur when refraction in the upper part of the refractive layer decreases more rapidly with height than in the lower part.

When either the observer or the object is in motion, the images can appear and disappear quite rapidly or they can seem to perform rapid gyrations creating the illusion of extraordinary spacecraft. In addition, interference between incident and refracted rays can produce complicated mirages, whilst focussing of the rays can "cause bright and dazzling images which jump about or even disappear at the slightest movement".

When an inversion is horizontally extensive, such as in a long ridge of high pressure, it is possible for light rays to be bent several times following the shape of the earth's surface, in much the same way that radar ducting takes place. When there is a wide horizon and an extensive inversion, it is possible to see the mirage of a light which may be 100-150km away. The light is usually on the earth's surface, but the image, often distorted, can appear as a light at low elevations in the sky.

It is important to remember that the atmosphere can act as a lens under refractive conditions and the size and intensity of images can be magnified many times. The magnification can be so great that large objects, like mountains or islands, have been "seen" at sea over verified distances of up to 1000km (The Marine Observer, 1971). Each instance of long distance mirages is associated with a pronounced and widespread inversion, such as those found in long ridges of high pressure.

One of the best examples of refracted lights in Australia would be the "Min-Min Lights" of Queensland. Invariably, there is never a sound, nor any physical trace, when these ghostly lights are seen bobbing up and down above the tree tops. In each case there is ample evidence for a marked inversion, and the direction of the ghostly light fits in with the direction of a distant stretch of highway, sometimes 100-150km away. The brighter lights come from truck spotlights on high beam, used to assist in avoiding kangaroos and wandering stock, but Min-Min lights have been known to be caused by distant cars. These bizarre lights in the sky are never seen on windy or cloudy nights, but only on occasions when it is fairly calm and clear, the atmosphere being stable enough for inversions to occur.

And the Nullarbor lights are the same. You will never see them on windy or cloudy nights. On clear, calm nights passengers waiting at sidings on the long, straight transcontinental line have reported seeing the light of an approaching train for at least an hour before it actually arrived. At the normal speed of the train, 110km per hour, people must have been able to see the the headlight of a train which would be at least 110km away at the time. It first appears as a light in the sky, and only in the last 10 to 15 minutes does it "come to earth" as it were. Australian National Railways advises that, at high beam, these lights are of approximately 2000 candle power. It is no wonder that their refracted lights can be seen at such great distances over the flat Nullarbor. The Brown Mountain UFOs (Klass, 1974) are good examples of refracted lights from American trains, but in much more irregular country.

The very scattered road traffic over the Nullarbor must also generate mirage-type lights in the sky, particularly from some of the interstate transport trucks which are especially equipped for night travel. Campers on the Nullarbor report strange lights at times, some of which could be attributed perhaps to activities at the Woomera Rocket Range. It is interesting that one of Australia's best hoaxers, the "Nullarbor Nymph" (Geneice Brooker Scott) spent many nights posing as a wild girl living with kangaroos, and confirmed that she has seen lights in the sky. She has said,

"They could be meteorites, or satellites, - or something else!"

But to return to the 1988 incidents. The unusual lights seen on both occasions were obviously refracted images of distant light sources, because both occasions were associated with

pronounced temperature inversions. If additional confirmation is needed, the light seen on 20th January 1988 "jumped about a bit", typical of refraction focussing, and was elongated in the vertical, which fits the towering type of distortion that one would expect from the inversion shape on that particular night. The inversion on 17th October 1988 should have given rise to a squat, horizontally elongated image, but Mr Chapman did not specify its shape.

It is one thing to be confident about refraction being the cause of an image in the sky, but quite another to find out what actually caused the light which was refracted. So much depends on the attitude of the light source and the height and strength of the inversion that it is difficult to specify what distance would result in the type of focussing necessary to produce a bright and dazzling image.

Let us consider the observed facts on both occasions. The Knowles family on 20th January saw the light to the east which they "first thought was a truck approaching them from the east". There were no bright astronomical bodies in that direction and the sun was 29 deg below the horizon. Besides that, its azimuth was 145 deg. There were however, several vehicles, both east-bound and west-bound, on that section of the Eyre Highway at the time (Basterfield and Brooke, 1988). Although some of the other drivers reported no unusual lights, it should be remembered that this is typical of situations conducive to refracted lights.

It is difficult to determine which vehicle was in the correct position to permit focussing of the refracted light and cause a "bright and dazzling image", but one cannot rule out a west-bound vehicle descending into Eucla, 100km to the East, because of its elevated position. A vehicle at that distance would not have been considered to be part of the incident.

This leads to the conclusion that the first impressions of the Knowles family were correct, ie. that it was indeed "a truck approaching from the east". It was the distorted image of the headlights which was so frightening and bizarre. All the other things that happened to their vehicle were either of their own doing or their own imagination while in a state of fright, as none of their claims in this regard were substantiated by inspections of their vehicle.

The vertically elongated image observed by the crew of the tuna boat on the same night would obviously have been from a different light source. Nevertheless, the tuna boat was still near the ridge of high pressure and the same widespread inversion would have covered its position. So they too would have observed a refracted light in the sky, but without any indication of direction it would be impossible to say what the light source was. The most obvious choice is perhaps another ship.

In the second incident, the light appeared to be "hovering about 20m above the ground" and "on the right-hand side of the bus", the most likely direction being from the north-east. Basterfield (1988) identified the light source as being the planet Jupiter and indeed its position (azimuth 040 deg, elevation 26 deg) seems correct, especially as the observation was made over a line of low hills and the sky was almost cloudless. There is no doubt that refraction in the inversion layer would have changed this normally bright light into a distorted and enlarged image. In addition, it was recorded that the driver and passengers were aware that they were almost exactly in the area of the first incident nine months earlier and they certainly have been looking for lights.

It is interesting that Australian National Railways advised that there was a west-bound goods train between Denman and Hughes, approaching the W.A./S.A. border at the precise time and date. The bearing of this light was 040 deg from the sighting position, but the distance, 170km, puts it slightly out of range, especially in view of the line of 100m hills between the headlight of the train and the observer. Nevertheless, mirages have been observed over that distance.

In view of the fact that the bus driver and passengers saw only one light, it must have been the planet Jupiter. They would not be the first to call planets UFOs. This is quite easily done when refraction distorts their normal shape and intensity. Even a scientifically trained naval officer, who later became U.S. President, Jimmy Carter, called Venus a UFO at one time (Sheaffer, 1981). The impression of being chased by the light is common when the observer is moving.

So, if anyone is looking for UFOs (strange lights), they should certainly try the wide open spaces of the Nullarbor. But stay near the highway, as this is the best producer of unusual lights. Never choose the windy nights or the cloudy nights. It is necessary to have the fairly calm, clear nights which are indicative of inversion conditions when refraction occurs. Best of all, choose a night when the high pressure centre is near you, or a long ridge of high pressure extends over you.

Even though there is a roadside sign near the W.A./S.A. border warning travellers to beware of UFOs, it is hoped that you will be better informed. There are quite a few occasions each year when pronounced inversions cover the area, so be on the lookout for them. However, the type of refraction focussing such as the Knowles family experienced is much rarer. The light source has to be at the right focal length and the height and strength of the inversion have to be just right for a large dazzling image to appear.

If you see a strange light, stop, note the time and take rough bearings of the direction and elevation whilst watching its movement, reporting this to the nearest Police. There is no need

to be alarmed, or to panic like the Knowles family. No one has ever been hurt by such lights. Rest assured - we are not being invaded by extra-terrestrial beings from wherever - the unusual lights are naturally occurring refraction phenomena. Many of the "UFO" interpretations seem to come from people who ignore the known wonders of our atmosphere; they seem to be unaware that science fact is much more full of wonder than "UFO" fiction!

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Fig. 1

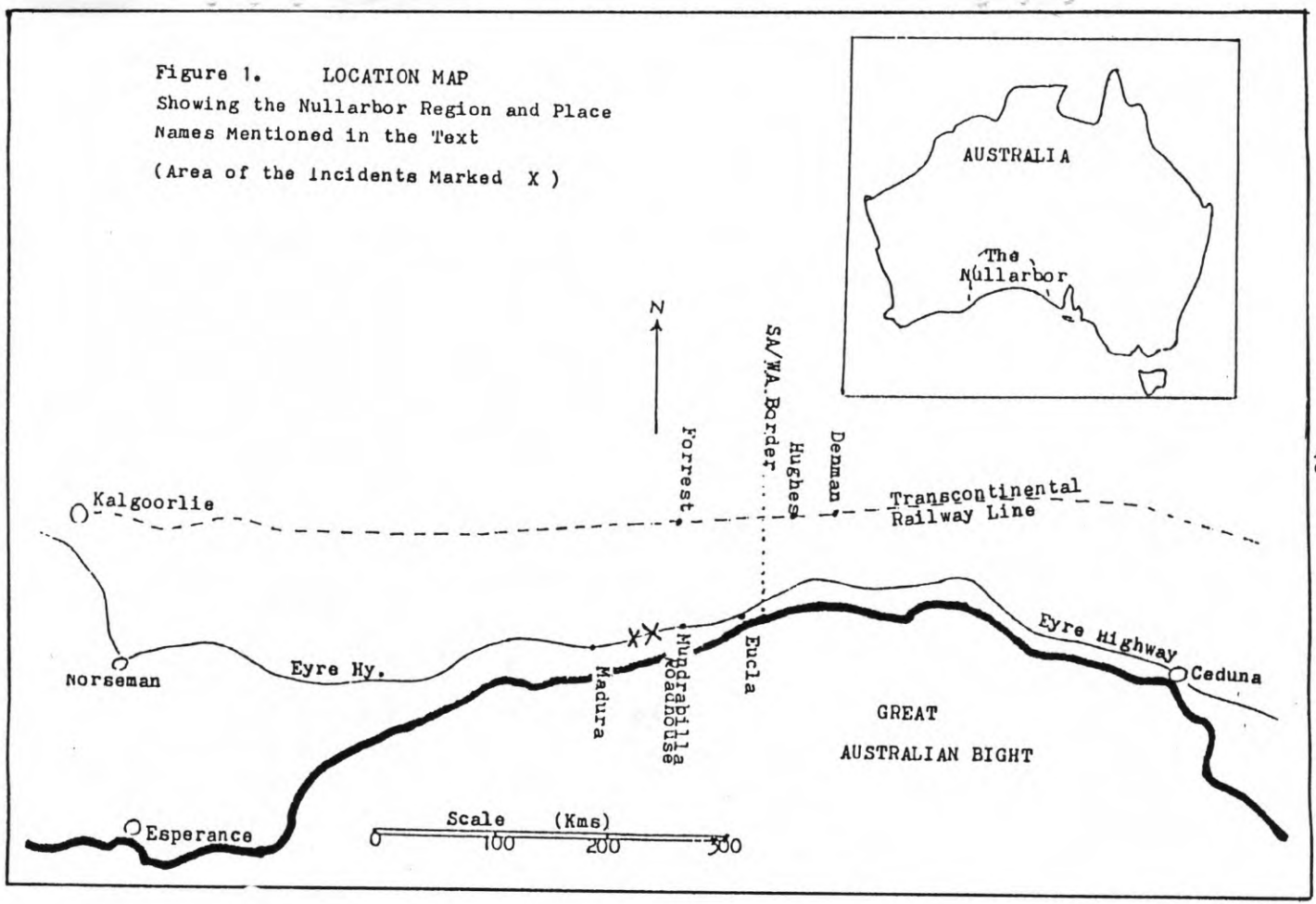
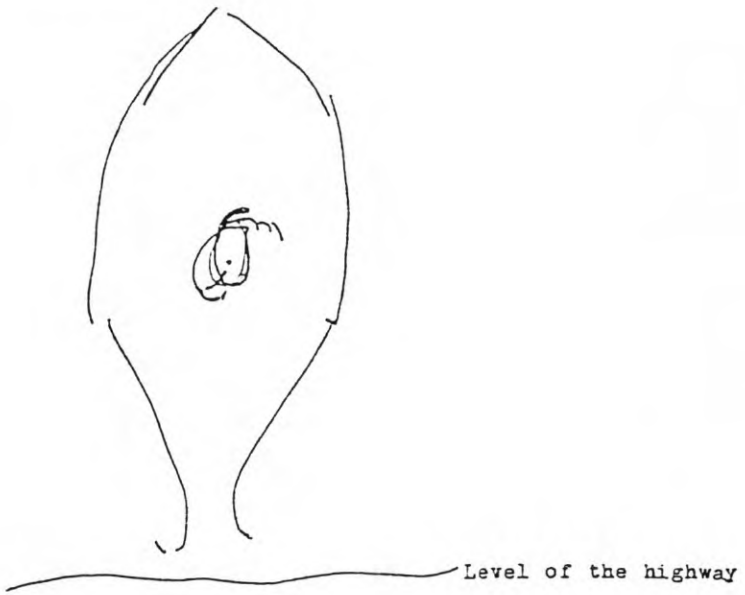


Figure 1. LOCATION MAP
Showing the Nullarbor Region and Place Names Mentioned in the Text
(Area of the Incidents Marked X)
AUSTRALIA
The Nullarbor
N
Forrest
SA/WA Border
Hughes
Denman
Transcontinental Railway Line
Kalgoorlie
Norseman
Eyre Hy.
Madura
Mundrabilla Roadhouse
Eucla
Eyre Highway
Ceduna
GREAT AUSTRALIAN BIGHT
Esperance
Scale (Kms)
0 100 200 300

The Shape of the "UFO" Drawn by Sean Knowles after the Sighting on 20th January 1988. Copied from 'The Advertiser' of 21st January 1988.



Note the vertical elongation and the fact that the light was well above the road. In the bright centre, which the Knowles family said was coloured yellow, one can almost discern the shape of two headlights. A good example of the 'towering' type of distortion due to refraction in a temperature inversion where the refractive index increases with height.

Fig. 2

Upper Air Temperature Profiles at Forrest Showing
Pronounced Temperature Inversions
Nearest to each Incident Time

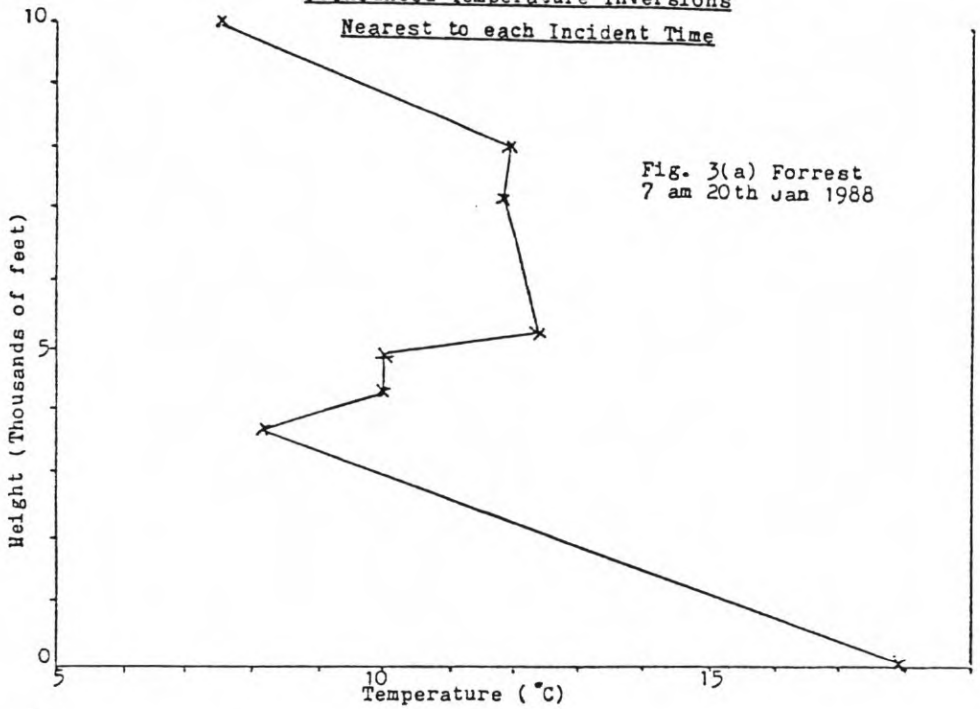


Fig. 3(a) Forrest
7 am 20th Jan 1988

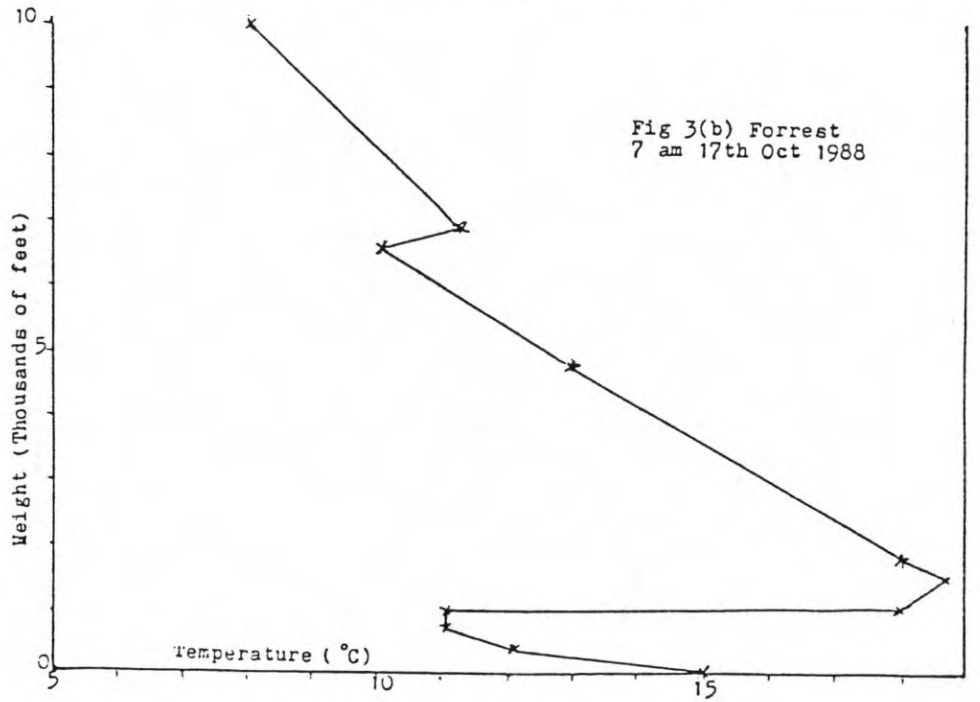


Fig 3(b) Forrest
7 am 17th Oct 1988

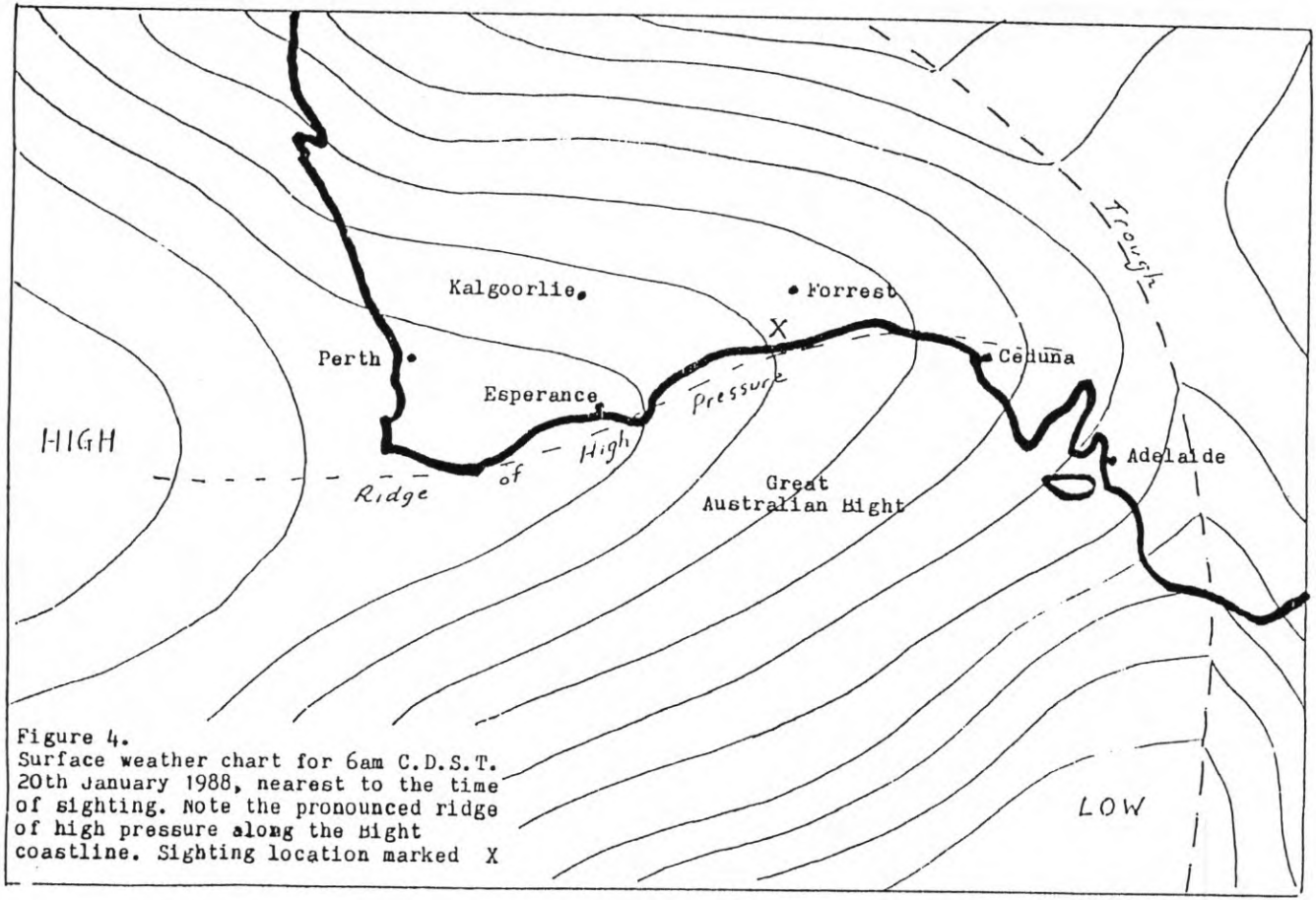


Figure 4.
Surface weather chart for 6am C.D.S.T. 20th January 1988, nearest to the time of sighting. Note the pronounced ridge of high pressure along the Bight coastline. Sighting location marked X

Fig. 4

Fig. 5

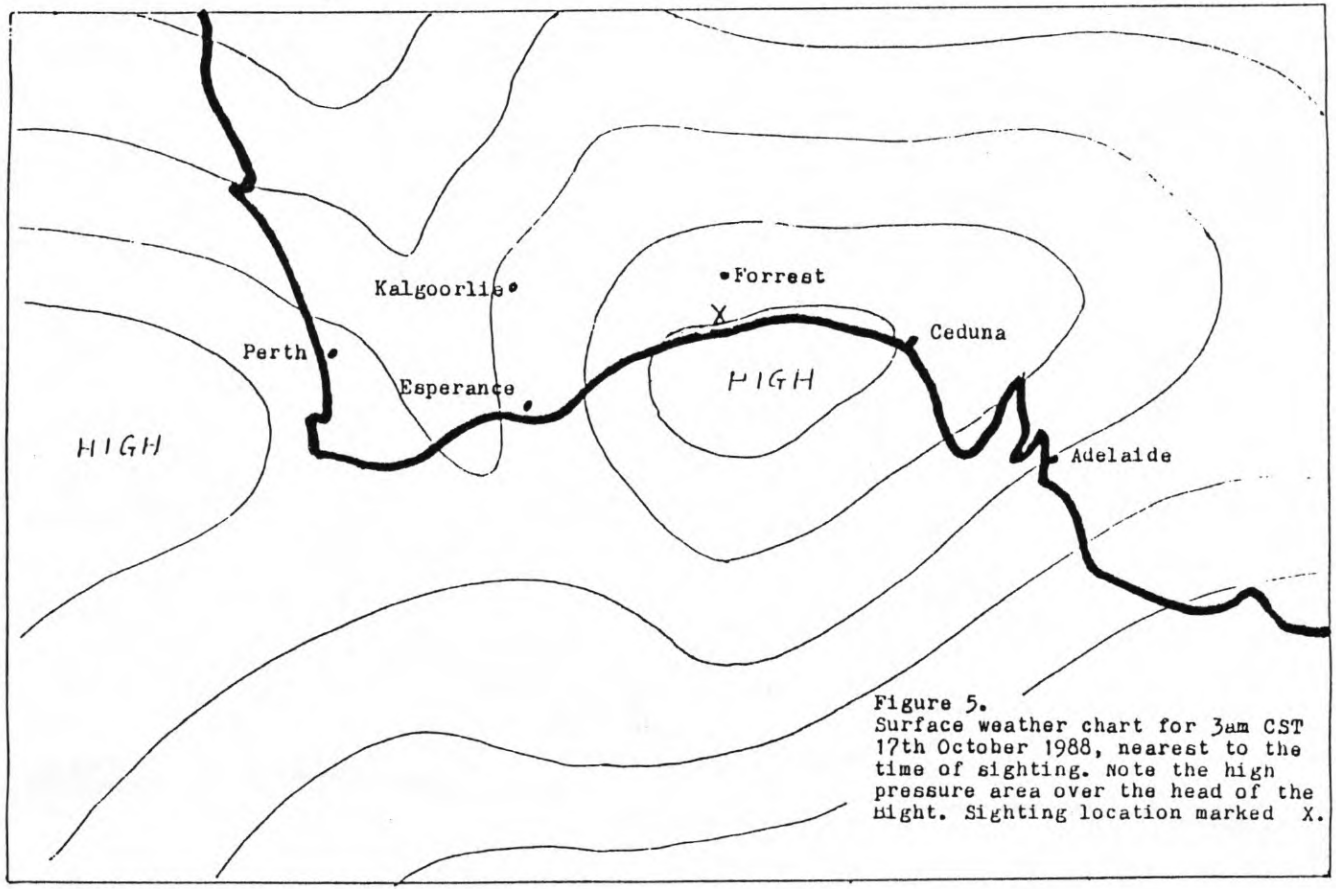


Figure 5.
Surface weather chart for 3am CST 17th October 1988, nearest to the time of sighting. Note the high pressure area over the head of the Bight. Sighting location marked X.

Figure 6.
Light wave fronts distorted in a temperature inversion to produce a superior mirage. The light source may be a truck on the highway ahead, but the observer sees (at right angles to the wave front) a bright light in the sky.
Angles exaggerated for illustrative purposes.

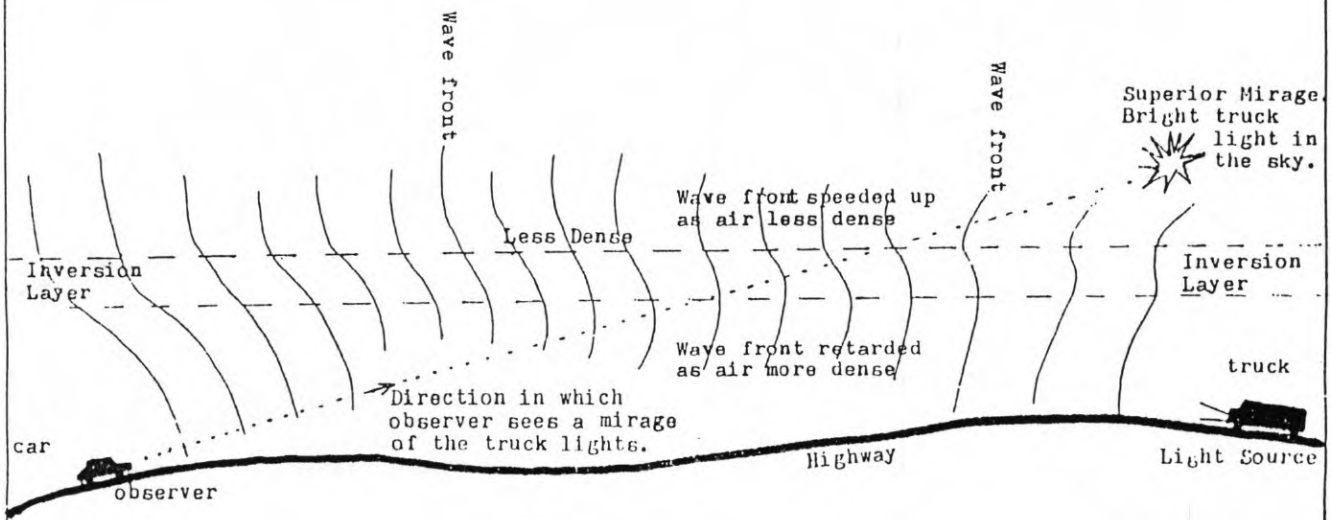


Fig 6